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THE PLACE OF X-RAY CRYSTALLOGRAPHY IN THE DEVELOPMENT OF MODERN SCIENCE

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VON LAUE'S discovery of the diffraction of X-rays by crystals effectively provided science with a new eye with which to see the ultimate arrangement of the nuclei and electrons of solid matter. It is true that X-ray analysis does not show atoms and electrons to the eye in the way that a microscope does; the process of interpretation is more complicated, but it is essentially analogous. In an ordinary optical instrument the interference of rays from luminous points is used to build up the optical image by means of a lens system. In X-ray analysis the interference pattern is taken and interpreted mathematically instead of optically to give the nature of the object observed, so that it is just one step farther removed from our inherited mechanism for appreciating the external world.

Now we have had this new eye only seventeen years, and although it has shown many marvellous things and enabled us to build for the first time a picture of the intimate structure of solid matter, we cannot believe that it has more than begun to be used. Many more important discoveries are bound to follow from it, and it has still to find its place as an essential instrument in every branch of scientific research. The object of this article is to point out what can already be seen of its possibilities and how it is likely to affect science in the near future.

THE THREE FORMS OF INFORMATION FROM X-RAY DIFFRACTION

Apart from the knowledge given on the nature of X-rays—which was of such critical importance in the discovery of atomic numbers and in the verification of Bohr's quantum theory of radiation—the diffraction of X-rays by crystals yields information about three grades of fine structure of matter. Ultimately the diffraction of X-rays is due to the interaction of the radiation with the electrons in the atoms of matter, and so the deepest information it can give is on the position of the electrons in the individual atoms, or, more correctly, information as to the average distribution of density of negative electricity. Here it is most closely related to pure physics and leads to the possibility of the complete description of the state of any piece of matter. But without going nearly so deeply, X-rays can show the position of the maxima of electrical density, that is, the position of each kind of atom, in a regular crystalline structure. It is in this field that the chief work of X-ray crystallography has been done. It is faced with the extensive problem of determining all the different possible types of atomic arrangement in solid substances, which has such a clear bearing on chemistry. Besides these two types of information, the diffrac-

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tion patterns of crystals may be used as in ordinary crystallography to fix the nature and orientation of the minute crystals which go to build up common substances, with the advantage that there is no limitation to the substances which can be examined in this way, and a means is provided for analyzing all the textures of natural and artificial products. This is the type of information which links X-ray crystallography to biology on the one hand and technology on the other. The three types of information are not independent; strictly, the physical description underlies the others, but pending such complete description they have their immediate uses and we will treat their scope and possibilities separately.

X-RAY DIFFRACTION AND ATOMIC PHYSICS

So far as we know, the determination of the quantum numbers of every electron, which includes the allocation of that electron to a particular atom or group of atoms, gives the most complete picture of the state of matter that is available to us. Up to the present this complete description has been confined to single atoms in gases, to simple molecules, and to ionic crystals of simple types, such as the sodium chloride type, and here evidence from X-ray diffraction cannot stand alone but must be combined with the deductions of theoretical physics and the data of spectra in the ultra-violet, visible, and infra-red fields. What the X-rays give are the so-called F curves, which are measures of the internal interference of electrons in the same atom, and from which the radial distribution of the electricity in the atom can be calculated and used to check deductions made from other grounds. Unfortunately, X-rays are least sensitive to variations in the outer regions of the atom, which are the most important for the optical, magnetic, and chemical properties of the substance. But the exact determination of

F curves is only beginning and it would be unwise to put any limitations on their possibilities. The great advantage the X-ray methods of examination have against the spectral is that they give information as to the ground or lowest energy states of the atoms, whereas the other methods necessarily deal with excited atoms and only inferentially with atoms in their normal state. This is particularly important in the case of metals where the state of a metal examined spectrally may be very different from what it is in the solid.[1]

STRUCTURAL CRYSTALLOGRAPHY

The determination of atomic positions in crystals is rightly considered the chief function of X-ray crystallography. The methods for doing this have been gradually perfected, particularly through the work of W. H. Bragg and his school, until they can deal satisfactorily with crystals of low symmetry and with a number of different atoms. The chief difficulty has been that all determinations of atomic positions must be indirect. It has, up until now, proved impossible to determine atomic positions by direct calculation from the intensities of diffracted beams of X-rays. The inverse process is, however, straightforward: from a known distribution of atoms it is possible to calculate exactly these intensities, and the problem reduces itself to finding by any means whatever a plausible structure and then establishing it accurately by means of numerical correspondences between observed and calculated intensities. Thus it happens that, although it is quite possible that the structure of an examined crystal cannot be determined at all, its determination, when it is carried out with sufficient care, can be relied on to give the exact positions of the atoms.

[1] For instance, Pd has a spectral S state, which, if preserved in the metal, would render it diamagnetic, whereas it is in fact paramagnetic.

THE IMPORTANCE OF CRYSTAL STRUCTURE
TO PHYSICS

Very naturally the determination of a great number of structures has had to be carried out before their full importance to the physicist and chemist could be realized. To the physicist who is concerned with studying in detail the properties of a single substance, the relative positions of the atomic centers—which we designate as the structure—is important as the basic framework for any deduction of properties. It is not complete: that would require a description of the electrons and their quantum numbers themselves, but it is the minimum basis which must find a place in every formula expressing a physical property of the substance. The properties of substances may be divided into three types: those independent of structure, because they depend only on the properties of the individual atoms, such as the absorptive power for X-rays; those which depend on structure but are chiefly concerned with the immediate neighborhood of atoms in the structure, such as density, elastic constants, optical and magnetic properties, etc., and those which depend on the perfection or imperfection of the crystalline nature of the substance, such as plastic deformation, electrical conductivity, etc. It is the second group of properties that the structure determined by X-rays has been most useful in elucidating, but the third group has also yielded not so much to the X-ray determination of structure as to the determination of texture, which will be dealt with later.

CRYSTAL CHEMISTRY

But the importance of crystal structures to the chemist is far greater than to the physicist. So far, chemistry has been essentially a science dealing with the gaseous and, in part, the liquid states of matter. In order to know anything at all about the nature of a solid the chemists had to decompose it into a liquid or a gaseous phase and infer from its behavior what its original state was. X-rays have given a means for the first time of determining the actual state of chemical combination in solids. The information they provide can now be used to build up a complete chemistry, in which the world of old chemistry is seen to occupy but one place in the general classification. So far, this is only a possibility: chemistry has yet to be re-written on the basis of structural evidence.

In the chemical examination of substances the first stage was the determination of the actual numerical proportions of the different atoms composing them; then, from the existence of isomers, there came gradually to be built up by inference the more elaborate structural formulæ. What the X-rays have done is to move the structural formulæ from the plane of hypothesis to that of measurement. So far, the function of X-rays and orthodox chemical methods have been roughly complementary. In the inorganic realm, and particularly in the metals and silicates, the comparative stability of the structures rendered the chemical analysis of them very difficult,[2] but X-rays, through the advantages of their good crystallization and the heavy atoms they contain, have been able to unravel their structures and reduce them to order. On the other hand, in organic chemistry with its separate molecules, its great possibilities of transformation, and the liquid state of so many of its compounds, chemistry had the first advantage, and so far X-ray work has been needed for the most part only to confirm the validity of the chemical formulæ of the molecules and to give the extra information of how they are attached together. But it

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2At any rate, so far as structural formulæ were concerned.

can hardly stop there. We have here a definite way of actually measuring relative positions and distances of atoms apart, and we may confidently expect that not only will X-rays be used more and more to determine structural formulæ, but no structural formulæ will be accepted unless its validity has been attested by X-rays. The peculiar advantage the X-ray structures have over the formulæ of the chemists is that, being metrical, they give the possibility of explaining the properties of a substance quantitatively from its structure. This knits the physics and chemistry of substances closely together and points the way to the inverse process of being able—given certain properties—to predict and then to synthesize the substance that will have them.

So far, however, it is for systematic chemistry that X-ray methods have been most valuable. Of the immense variety of substances, the great majority—and all the most complex substances—are solid at ordinary temperatures, and though every liquid or gas has a corresponding solid phase, the reverse is by no means the case. Consequently the classification of solid substances covers nearly all the field of chemistry. The classification of solids as it stands at present is based on the older chemistry, on the results of crystal analysis, and on quantum mechanics in roughly equal proportions. The three fundamental ideas are the knowledge of the types of interatomic binding forces and the concepts of co-ordination and atomic diameter. The latter two were in the first place chemical ideas, but were given a precise form through X-ray crystallography, particularly through the work of the Braggs, Goldschmidt, and Pauling. Alone, they would furnish the basis for a formal geometrical classification. But for a natural classification, one which would group together substances according to their physical and chemical properties, it is necessary to invoke the nature of forces between

atoms. These forces, metallic, homopolar, ionic and Van der Waals, derive from the old valences of the chemists and the forces of cohesion of the physicists, but only through quantum mechanics have they received a rational explanation in terms of electronic structure. The new system of classification depends on an intricate blending of these ideas. We first divide crystals into the general physical types, metallic, homopolar, adamantine, ionic, and molecular, according to the type of the chief force binding the crystal units together, the units being simple atoms or complex molecules or ions themselves held together by other forces. Inside this, the crystals fall into divisions on geometrical grounds based on their co-ordination, atomic diameters, etc., a process of classification of which, owing to the small number of substances examined, only the general lines can be seen. It is worth while examining the leading physical types to see how much of our knowledge of them is due to the study of their structure and how much information we may expect from it in the future.

THE NATURE OF THE METALLIC STATE

It is astonishing, considering their simplicity and the extent to which they have been studied, how little was known up to a few years ago of the inner nature or even of the chemical composition of metals and their alloys. Thermal and micrographic analysis had enabled the equilibrium diagram to be determined for a number of systems, but what each phase in the diagram stood for, the meaning of the various compounds and solid solutions which seemed to have no relation at all with the ordinary laws of chemistry, was completely obscure. So also was the relation of the composition of metals to their physical properties. With the X-rays came a new era in the study of metals. In a single paper Hull determined the structure

of nearly all the common metals and showed the extremely simple way in which their atoms were fitted together in a close packing, which was afterwards to prove the characteristic structure property of metals. Since then, the field of alloys has also yielded its secrets. Very considerable work has been done on pure metals, alloys, and alloy systems, particularly by Westgren and his school. The characteristic of a phase in the equilibrium diagram is seen to be a certain crystal structure and not in the ordinary sense a chemical compound. Its composition may not be fixed, because, owing to the extremely generalized attraction between metal atoms, any atom may be replaced by another (within certain limits of size and electronic configuration) without a change in the crystal structure. This is what gives intermetallic compounds a peculiar indefiniteness of chemical composition, while preserving fairly constant the physical properties which depend primarily on the crystal structure. At the moment, the laws of chemical combination of metals are just beginning to be found out and seem to depend more on geometrical and spatial considerations than on the chemical properties in the ordinary sense of the atoms concerned. This appears quite reasonable when we begin to see that what we are dealing with in the metal is not the atom as we see it in chemical compounds, stripped of its outer electrons as the ion, or sharing them with another in homopolar binding, but still holding them as an insecure outer shell, responsible at the same time for the mechanical cohesion of the similar atoms and for the electrical conductivity which can occur when they interchange electrons.[3]

But all this is only one side of what X-rays have done and promise to do for the study of metals. The mechanical proper-

ties of metals are of overwhelming technical importance and considerable theoretical interest, and X-rays have for the first time enabled us to see what is going on in a metal subjected to mechanical stress. The problem was a very complex one, and it was seen that the first simplification required was to deal, not with a confused mass of small crystals, but with single crystals, the manufacture of which was largely a by-product of X-ray methods. In single crystals the process of hardening by working or by alloying with small quantities of foreign metals has been followed simultaneously mechanically and by X-rays, the particular glide planes of the different metallic lattices and their differences of behavior have been experimentally mapped out, but the greater part of the task —the devising of an adequate theory based on fundamental physical concepts—has yet to be developed. The inspiration for it must come from the wave mechanics, but at every point X-ray analysis will be required to check it. Once we have suggested a theory, or even an approach to it, metallurgy will cease to be what it has always been in the past—a thoroughly empirical science requiring an enormous amount of haphazard experimentation to find a single valuable technical process—and become a branch of physics, having the practical advantage of being able to reveal, by means of calculations, the exact composition and treatment required to make an alloy having any desired properties.

ADAMANTINE COMPOUNDS

Closely related to metals and forming the bridge between them and ionic chemical compounds are the compounds called adamantine or homopolar, which occur in nature chiefly as the ores of metals, and in industry as slags. Of these compounds of metals with atoms of the carbon, phosphorus, and sulphur groups, the chief bin-

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[3]This seems to hold for true metals, iron, copper, etc., and their alloys with each other, but in case of alloys of the tin or antimony groups, etc., there seems some evidence for homopolar bonds and even for ions.

ing forces are homopolar, the whole crystal forming one large molecule. As in the case of metals, their chemistry was very obscure, as the compounds were indefinite in composition and no ordinary valence relations seemed to hold. The X-ray study of this group has not yet proceeded very far, but already it seems to show that the compounds are reducible to a few leading types. Of these, the chief is the diamond—zinc blende structure—in which every atom is bound to four neighbors by homopolar bonds. This is the basis of the structure of a large number of sulphides, carbides, etc., containing a roughly equal number of metallic and non-metallic atoms. The next simplest is the nickel arsenide type, of which each atom is bound to six others with homopolar bonds. This, or structures deriving from it, accounts for a great number of simple and complex arsenides, antimonides, and stannides. Where the non-metallic atoms are in excess they hold together by homopolar bonds and form molecular units, leading to structures of the pyrites and calcium carbide type. In this field, which forms the bridge between metallurgy and mineralogy, X-rays have an important part to play. On the mineralogical side, for instance, as the substances are for the most part opaque, the X-rays may take the determinative character that optical methods have in petrology. On the theoretical side the transition from metallic to the non-metallic study is of extreme interest, for it is in this region that such phenomena as photo-electric conductivity and high frequency rectification are found to occur.

IONIC COMPOUNDS

The field of ionic substances is the classical region of X-ray crystallography; the typical ionic crystal, rocksalt, was the first to have its structure determined, and it is in the more complex ionic crystals, particu-larly the silicates, that X-ray analysis has scored its greatest triumphs. In this field theory and experiment adequately supplement each other. The forces holding together ionic crystals, being for the most part simple Coulomb attraction, are naturally the first to be amenable to calculation, and the repulsive forces which balance them can be described empirically as due to semi-rigid atoms of definite radius or theoretically by a resisting force proportional to high powers of the inter-nuclear distance. The crystal analyses of W. L. Bragg for more complex compounds and of Goldschmidt for the simpler ones laid the empirical basis for a systematic classification of ionic compounds. To a first approximation it can be based on the concept of atomic diameter and co-ordination numbers, the latter depending only on the ratio between the diameter of the central ion and that of the ions which surround it. Pauling has even generalized these conceptions into rules which can be used for predicting the structure of compounds of known composition and even predicting which will be the stable compounds in mixtures of metallic oxides. The idea of a measurable atomic diameter is bound to have immense repercussions in inorganic chemistry, particularly the picture of the large, easily polarizable negative ions and the small, effectively polarizing positive ones. It explains, for instance, the formation of complex ions by elements of the fourth, fifth, sixth, and seventh groups and the great preponderance of ions of the type AX_4 among them.

The main divisions of ionic compounds have also become clear. First come simple oxides and halides of the general type $A_m X_n$, which are further subdivided according to the co-ordination number of the negative to the positive ions, varying from 8–4. Next we have complex oxides and halides in which a number of positive ions varying in charge and diameter share an

equivalent number of negative ions. The great bulk of the silicates fall into this class and their complexity is seen to be largely a purely geometric one, the problem of a silicate structure being first to see that each positive ion has its proper co-ordination number of oxygen atoms, beginning with the smallest and most positive, which is generally silicon, and subsequently that each oxygen ion is surrounded by a number of positive ions, so that the total induced charge on it is as nearly as possible —2. In any structure satisfying these requirements there is still considerable freedom of choice of the metal ions, and X-ray analysis has for the first time explained the nature of isomorphous substitution in ionic compounds. In the first place, ions of the same charge and approximately the same diameter are virtually interchangeable from the point of view of structure; such, for instance, is the group Mg^{++} Fe^{++} Ni^{++} Co^{++} Mn^{++}. But size is more important than charge, and ions of different charges and similar sizes are interchangeable if compensatory changes take place elsewhere in the structure; such, for instance, as the Ca^{++} Al^{+++} $Na^{+}Si^{++++}$ substitution in the felspars. The chemical constitution of silicate minerals has been a region of immense speculation and formula-building. X-ray analysis has already introduced an extreme simplification and shown itself to be indispensable to the proper understanding of their nature.

After the complex oxides come the complex ionic compounds of which the commonest are the Oxy salts. Here the units are the ions of determinate form, such as sulphate, perchlorate, beryllofluoride, ammonium.[4] The types of crystal formed closely resemble those of the simple or complex oxides and halides, differing only in having

in general a lower symmetry due to the substitution of the complex ion for the spherically symmetrical simple one. Beyond the complex ionic compounds come the co-ordination compounds, ionic compounds containing neutral but in general strongly polar molecules, such as water and ammonia. This field has been least explored by X-rays, but its most symmetrical members show how extraordinarily exact were the ideas which Werner enunciated about these compounds. The polar molecules cluster round the smallest and most highly charged ions[5] forming larger ions which build up crystals exactly as simple ions do. Already the general classification of inorganic salts is clear: it requires only expansion to cover the case of unsymmetrical and large complex ions such as perchlorates, silicotungstates, etc. It is, however, apparent that such ions will fall into two types—closed and open. The closed type consist of high-group atoms sharing oxygens between them, of which the simplest are the dichromates, but which may have the complexity of rings or even baskets, as in the silicotungstates. These ions still behave as simple ions in the crystal except in so far as their peculiar shape interferes with the symmetry in the crystal and in solution. In the other type, which is that of the silicates and probably a number of phosphates and similar salts, the linkage of high-group atoms through oxygens continues throughout the whole crystal. It may take the form of simple chains or ribbons, of plates or spatial lace-work. Such crystals are necessarily insoluble without decomposition and their physical properties depend almost entirely on the form of their ionic network, e.g., fibers of asbestos, plates of mica, hardness of quartz, etc.

MOLECULAR AND ORGANIC COMPOUNDS

There is no doubt but that organic crystals furnish greater complexity and variety

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[4]Whether the inner forces of these ions are homopolar or themselves ionic, probably varies from case to case, and there may be no real distinction between these two views. At any rate, there is none so far as the way they are built together to form the crystal is concerned.

[5]Their number seems to be determined by steric considerations rather than by those electronic rules proposed by Sidgwick.

of crystal types than the inorganic, but their study has so far only begun. This is partly on account of their complexity, partly because of their low melting points, and partly because, containing light atoms, they are less amenable to quantitative X-ray analysis.[6] The characteristic feature of organic compounds is the existence of separate molecules. This means that we have two forms of association to consider—the intra-molecular and the inter-molecular—and the properties and classification of organic compounds will be different according to which view we take as primary. To the chemist it is the intra-molecular structure that has chief importance, and the classification that follows depends mostly on the pattern of the homopolar linkage of the carbon, oxygen, hydrogen and other atoms that go to make up the molecule. But from a crystal structural point of view it is the way the molecules are bound together that is important. Many properties, particularly mechanical properties and physico-chemical properties such as solubility, depend on forces between molecules. Now in the building up of molecules as units in a crystal, the factor of chief importance is not the internal structure of the molecule but its general shape and the presence of active or inactive groups at its periphery. The formation of derivatives of an organic compound by substituting for one hydrogen atom a methyl, hydroxyl, carboxyl, or amino group, etc., is to the chemist a comparatively small change, but to the physical chemist or crystallographer it is important as determining the whole nature of the binding between the molecules. There is, consequently, besides the ordinary classification based on the molecular structure, a possibility of a new classification based on modes of packing of molecules which would approximate much more closely to the grouping of organic sub-

stances according to their properties. So far, too few substances have been examined to make this classification a practicable one; only in some cases can we see the lines along which it would run. For instance, all compounds which have as their outer radicals hydrogens attached to carbons, including all hydro-carbons and a certain number of their derivatives, seem to form structures based on the idea of closest possible packing of molecules, the attachments between them apparently deriving from the Van der Waal's forces between the hydrogens and neighboring molecules. The actual crystal form in this case depends solely on the shape of the molecule. If the shape is approximately spherical, the structure is a close-packed cubic one, similar to that of argon or nitrogen. Methane and even benzene seem to belong to this class. If the structure of the molecule is very elongated, the close packing occurs only in one plane and we can get layers with carbon chains perpendicular to them as in the long-chain hydrocarbons, naphthalene and anthracene. The introduction, however, of strongly polar groups, such as hydroxyl or amino groups, adds to the Van der Waal's forces the much stronger ones of Coulomb attraction, and we arrive at a crystal structure the type of which is ice, where the negative oxygen end of the molecule fits closely between the two hydrogens of the next molecule. Urea is one of the simplest organic crystals of this kind. More complicated but probably essentially similar linkages occur in alcohols and acids, in which polarity is not so definitely marked. Carboxyl groups seem definitely to attract each other in the crystal, forming a fairly neutral complex. This is exemplified by the monobasic fatty acids in which the effective molecule is a double one, behaving very like a hydrocarbon molecule, whereas in the corresponding dibasic acids the linkage is carried through the whole crystal, which behaves much more like an ionic one. A fur-

[6]It is possible that the use of electrons instead of X-rays for crystal analysis will remove this disability or turn it into an advantage.

ther case of molecular association is furnished by those so-called polymerized substances whose physical properties, particularly their mechanical properties and their lack of solubility, differ so markedly from their organic compounds. Here it is almost certain that the molecules are held together, not by electrically polar forces, but by homopolar linkages, so that one is really dealing with macro-molecules or open molecules of indefinite length in one, two, or three dimensions, exactly equivalent to the open ionic groups in the silicates and similarly associated with their physical properties. These different types of molecular binding are only roughly outlined as yet and simply point to a field of possible application of X-rays to organic chemistry. The complexity of molecules obviously makes it possible for all three types of binding to exist simultaneously in the same substance, and the task of X-ray analysis lies in the disentangling of these forces. Ultimately, also, X-rays will come to be used for the direct determination of structural formulæ. Up to the present they have been limited to verifying the tetrahedral valences of the aliphatic atom and the plane hexagonal character of the benzene ring. But in crystal analysis rapidity of advance depends on the number of structures already known and may consequently be expected to proceed with increasing acceleration, provided sufficient interest is felt in it in chemical circles. The knowledge of the exact metrical structure of an organic molecule is bound to have great importance, not only in structural chemistry, but in chemical transformations. The question, for instance, of steric hindrance will require a quantitative explanation, as also will many problems of catalysis. Already a connection has been shown to exist between the spacings of atoms in a metal catalyst and the type of reaction effected, and it seems plausible to suggest that for complex reactions the catalyst acts like the frame of a lace-worker, holding the complicated molecules in positions in which they can combine or decompose.

LIQUIDS AND COLLOIDS

X-ray methods, however, are not confined to the solid phases of organic compounds, but also extend to liquid and colloidal phases. The interference pattern of organic liquids depends chiefly on relative positions of atomic centers in the same molecule, and can be used to deduce them. Information is also given as to the mode of association of molecules in a liquid, with particularly interesting results in the case of solutions.[7] An even more partial method, applicable to liquids and even to vapors, is that of using electron waves instead of X-rays, as the former are more sensitive to light atoms, such as carbon and oxygen. For the colloidal state X-rays also yield important information. Simple dispersed colloids, metal oxides, etc., have been shown to be merely extremely small crystals. The miscellar colloids and gels seem to fall into two classes. In one case, as in the soap-like colloids, the colloid particles seem to consist of a number of molecules placed side by side in a condition intermediate between that of a crystal and that of a liquid and closely related to liquid crystals, whereas in other cases the colloid constituent is really a macro-molecule held together throughout by homopolar forces. If these linkages hold throughout the whole substance the fiber network forms a gel—if they are independent, a sol.

BIOLOGICAL STRUCTURES

Investigations of liquids and colloids bring X-ray methods definitely into the field of biochemistry, and already, particularly in

[7] Prins has shown, for instance, that in ionic solutions the ions form an approximately cubic lattice the interstices of which are filled with water molecules.

the determination of the cellulose structure, important results have been achieved. In many ways solid substances formed by biological action have greater regularity than when made in the laboratory. When mineral substances are deposited, particularly calcium carbonate or phosphate, it is nearly always in the form of single crystals or crystalline layers, but even when the substances are themselves complex or organic products regular crystallization seems more the rule than the exception. In the building of the cotton fiber, the cell deposits each day a layer of cellulose macro-molecules in parallel orientation to that deposited the previous day, thus making the single fiber approximately a single crystal. Similar relations hold for the building up of animal fibers, such as hair and horn, etc. Peculiar interest attaches to those natural products which have crystalline or amorphous forms according to their mechanical state, of which the first to be completely explained by means of X-rays has been rubber. Here the spirally curled molecules remain disordered until the rubber is stretched, when, by straightening out, they link side by side to form regular crystals which break down again on contraction. It is in this sort of behavior that the explanation for contractile animal fibers may be found, and there is certain evidence that muscular activity depends on the existence of crystals formed in each contraction. X-ray analysis, which has the advantage of being able to be applied *in vivo*, is bound to become an important auxiliary method in the study of biological processes, particularly if a technic can be developed of short exposures, enabling the existence of momentarily produced substances to be detected.

TEXTURE

It is only in exceptional cases that a substance is found in Nature in the form of single crystals. Most common substances are aggregates of large numbers of minute crystals. The size of these crystals and the way in which they fit together to build up the substance have been conveniently termed its texture. The importance of texture has always been realized, as the mechanical properties of matter in gross depend on it, particularly those directed properties we know as "grain." But except where the texture was very coarse it remained completely obscure until elucidated by X-rays. The X-ray analysis of texture depends on the superposition of the innumerable diffraction patterns due to each individual crystal in the substance, and can give information of four kinds: as to the mean size, the shape, the statistical orientation, and the state of strain of the crystals.

The full meaning of texture of a substance can be revealed only by combining an understanding of its mode of origin and its behavior under different treatments with the interpretation of X-ray diffraction patterns taken at every stage. This is an intricate but fascinating mode of study. Up to now it has been applied only to metals and textile fibers, but its field of application is much greater, for it holds the key to many technological, biological, and even geological problems. Nor will it in the future be limited to mere analysis and description of textures already existing, but will go forward to the synthetic constructure of textures having interesting or useful properties.

PRACTICAL APPLICATIONS

I have attempted to show in the preceding paragraphs the place that X-rays have already taken in the elucidation of fundamental physical and chemical problems, and the still more fundamental place they are likely to take in the future. But besides this so-to-speak pure application of X-rays, the X-ray technic has a range of simply instrumental application which is already recog-

nized in a few fields but is likely to become universal. These applications are essentially practical rather than academic and could affect every industry without exception. In the first place, an X-ray diffraction pattern of a substance is characteristic of its internal structure and, therefore, without interpretation can be used as a standard of structure and consequently of quality. It detects immediately two important types of variation —alteration of chemical constitution or adulteration by foreign chemicals on the one hand, and grain size, orientation of particles, and internal strain on the other. Thus, ultimately, X-ray apparatus will have to take its place in every factory as a testing instrument for raw materials and finished products. The fields where it has already been used for these purposes are, firstly, in metallurgy in connection with rolled sheets, wires, etc., and in the process of tempering.[8] In textile industries X-rays have been used to detect the parallelism of fibers of cotton, artificial silk, etc., which is closely connected with their strength. In ceramics also X-rays have been used for testing varieties of china clay and the proper firing of porcelains. It is very difficult to think of any industry to which it cannot be applied with advantage. In mining, for instance, the actual character of the different constituents in massive ores can be very easily determined by its help, and it is bound to have a bearing on the process of smelting. In a general way the X-ray methods can always be relied on to give further information and deeper understanding of practically every process which heretofore has been carried out by empirical and traditional methods, and ultimately to lead to its improvement.

It has already shown its value as an auxiliary method of chemical analysis. Every crystalline substance has its characteristic X-ray pattern which would enable it to be immediately recognized as soon as a sufficient number of substances have been examined as standards. The particular value of the X-ray method lies, however, in its discrimination between the existence of an impurity in the form of a foreign crystalline phase or as a solid solution, in the former case giving rise to extra lines, and in the latter to a shift in the lines of the pure substance, the amount of which is a measure of the quantity of impurity present. Another application that will undoubtedly be developed is X-ray petrology, which, if it does not supersede optical petrology, will be a very useful complementary method wherever the latter does not give sufficiently determinate information.

DEVELOPMENT AND ORGANIZATION

In the foregoing I have tried to show the importance and the possibilities of X-ray analysis, but these possibilities cannot be realized to the full unless the study of the subject is pursued on a sufficient scale and in a sufficiently co-ordinated manner, and at the same time find its proper place in relation to other subjects. At the present time I think it can fairly be said that it has passed the period of pioneer investigation which must necessarily be left to individual genius and initiative and is not susceptible to any organization. For its continued growth this stage must give way to one in which there is a centered and organized attack on the problems involved and where the isolated solutions of particular problems are followed up by a systematic exploration of the whole field. For this to be possible it is in the first place necessary that adequately trained workers be available in sufficient numbers, and this implies the introduction of the new crystallography as a regular part of university and technical college training. At the same time, the subject cannot flourish

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[8] The characteristic interstitial carbides of steel, for instance, are shown to form in thin layers on the surface, depending on the method of heat treatment and consequently forming a check on it.

unless the assistance that it can give to other branches of knowledge is more fully realized and consequently its teaching must be arranged in relation to the physics and chemistry with which it is so closely connected. There should be no question of setting up a new and separate subject of X-ray crystallography. Though its object in the first place must always be to deepen our knowledge of the structure of matter, its chief utility will always be the fundamental assistance it gives to the process of knitting together all physical science into an harmonious whole.

THE RELATION OF DIETARY TO THE EFFECTS OF LARGE AMOUNTS OF X-RAYS ON THE ORGANISM[1]

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IN EARLIER work dating from 1926, we devised a means whereby we could determine through biological tests on animals the nature of the action of graded doses of X-ray energy on the organism (1). We noted early in this work that the initial dose of X-ray energy produced a gastro-intestinal disturbance in animals, very similar to the gastro-intestinal disturbances which we obtained by the addition of increased quantities of Vitamin B to the organism. In work preceding this we had demonstrated that the *Bacterium tumefaciens* in the early culture produced Vitamin B when grown in potato decoction (2). Rats given a ration deficient in Vitamin B showed no signs of Vitamin B deficiency when the early culture of *Bacterium tumefaciens* was added to the ration; neither did they show toxic symptoms. The weight curves of these animals corresponded to the weight curves of animals which were given relatively small dosages of X-rays (3). When the *Bacterium tumefaciens* is allowed to overgrow the medium in which it has been transplanted, the time interval necessary being fifteen days or more, the result of our feeding experiments showed that this culture imparted Vitamin A to the organism when added to a Vitamin-A-deficient diet (4). We found also that by increasing the dosages of X-ray, the larger dosages imparted Vitamin A to the organism (5).

At that early time these data were obtained by an analysis of the weight curves of animals on Vitamin-A-deficient diets. The X-ray energy was administered in the form of general body doses. In later studies it was interesting to note that by inducing a third degree erythema 1 cm. in diameter on the posterior surface of the neck of a rat, the animal was protected against a vitamin deficiency on a Vitamin-A-deficient diet for a period of ninety days. Control animals in the same series in which this was not induced, showed definite signs of Vitamin-A-deficiency within thirty days.

Thus, the process taking place in the culture of *Bacterium tumefaciens* may be compared with that which takes place in the animal body to which X-rays are administered. As the culture overgrows the medium, the organisms degenerate, and as this process becomes more complete, more of the fat-soluble constituents are liberated from the protoplasm. In the early culture, before degenerative processes have set in, the water-soluble constituents are liberated in the medium.

Thus, with the X-rays, the smaller doses cause the body cells to liberate the water-soluble constituents in which are contained the cell stimuli. With the larger doses, death of the cell occurs, or, at least, a partial destruction of its protoplasm takes place and this causes the liberation of the fat-soluble constituents, of which Vitamin A is a part. If this occurs in a local area of the body, the remainder of the body will be supplied with these constituents from this area for a period of time. If the process takes place throughout the whole body, the fat-soluble substances must be supplied to the animal body from without or death of the animal will result.

In working with lipoid solvents, such as coal tar, Mazola oil, mineral oil, etc., we have noted that upon the introduction of the

solvent into the subcutaneous tissue, hyalin-
ization of the tissue occurs about the mass
of solvent (6). When the solvent is applied
to the skin we obtain a keratosis (7). In
previous papers we have discussed the rela-
tionship of keratosis to hyalinization and the
relationship of both of these to hyperplasia
of tissue. They become important from the
standpoint of hyperplasia in that our studies
of previous date have shown that the hy-
perplasia or increased cell activity of the
fixed tissue type is due to the presence of a
stimulus in amount above that of normal in
body tissue. The increased amount of this
stimulus can be brought about in two ways:
by a direct addition of the stimulus to the
tissue, as, for instance, the addition of Vita-
min B or embryonic tissue to a dietary, by
the application of a relatively small amount
of X-ray to the body, or by adding embry-
onic or malignant tissue juice to a tissue
culture. The most striking, or, at least,
lasting, evidence of the presence of cell
stimulation in the body is found, however,
when we have removed a certain quantity
of fat-soluble vitamins from a localized area
of tissue. The fat-soluble vitamins may be
removed by any lipoid solvent or they may
be removed from a more local area of tissue
by the giving of a larger dose of X-ray.
The striking pathological picture in either
of these conditions is that of hyalinization,
and we have come to the conclusion that a
hyalinized tissue is one which has lost all or
part of its fat-soluble vitamins. Hyperpla-
sia in these conditions occurs in areas adja-
cent to hyalinized areas. In other words,
the hyalinized tissue is depleting slowly the
fat-soluble vitamins from the non-hyalinized
tissue, and if there are cellular areas in this
zone they will undergo hyperplasia, while if
the conditions are proper for such a change
to take place, actual cancer may develop.
This is seen clearly in X-ray erythemas.
The epithelium adjacent to the hyalinized
tissue produced by the action of the X-ray
undergoes hyperplasia, but more marked

hyperplasia occurs in the hair follicles, the
X-ray having hyalinized the tissue surround-
ing them, the follicles themselves not being
destroyed with the same amount of X-ray
energy.

Thus, these studies have led us to believe
that the more important of these two sub-
stances is the fat-soluble constituent of the
tissue. The greater importance of this sub-
stance may be accounted for by the fact that
the stimulating substance is water-soluble.
This has been shown by dialysis and other
biological tests (7). Thus, it can be consid-
ered as a more evanescent substance, one that
interchanges frequently throughout the life
of the animal. But the fat-soluble substance
is more stable in character and thus is less
easily removed. By gradually increasing the
general body dosage of X-rays given to
these animals, we noted that the protective
action of these fat-soluble vitamins became
less marked, and with a dose of 125 ma.-
min., or 155 r, administered twice a week,
the protective action of the diet was not ob-
tained until we had increased the Vitamin A
in our general diet to from 3 to 5 per cent
above the normal content of a well-balanced
ration (8). Thus, these observations tend
to support the view that X-rays act to cause
molecular disintegration in the cell. With
small doses we obtain a stimulation. Thus,
with those small dosages we must be merely
causing a slight disintegration and we may
assume this disintegration involves only the
water-soluble elements of the cell. As we
increase the dosages we are disturbing the
more stable elements of the cell in that we
are causing a complete disintegration with
higher dosages, or with dosages which are
localized to a small area. We can determine
the cellular change microscopically in the
localized areas, and we have grounds to as-
sume that a lesser degree of the same disin-
tegration takes place in all of the cells of
the body when this dosage is given in the
form of a general body dose. It was found
that Vitamin A alone added to a diet not

balanced in other constituents was not suffi-
cient to protect the animal against the large
dosage of X-ray, but that a well-balanced
dietary had to be given. In other words,
the animals which withstood best the higher
dosages of X-rays were given a stock ration
of dog biscuits, corn, vegetables, small
amounts of meat *ad lib.*, to which was added
the fat-soluble vitamin. These diets were
prepared in such a way that the animal
would eat an amount larger than ordinary.
As noted by the protocol and weight curve,
the fat-soluble vitamin may be given in a
number of forms, the important factor being
the amount. This was not so markedly
shown in the studies of coal tar intoxica-
tion. A chemical ration to which cod liver
oil was added protected the animal against
coal tar intoxication almost as well as a bal-
anced stock ration to which the same amount
of cod liver oil was added (9). However,
coal tar intoxication is the result of the
changes taking place between the body and a
localized area. Thus, this can be compared
to the X-ray erythema, while it cannot be
compared to giving a general body dosage of
X-ray. When we commenced our work on
the action of X-rays on cancer and normal
tissue, we believed that the X-ray killed the
growing cells entirely by acting directly on
them. The work of Canti with the action of
radium on cells *in vitro* gave one the same
impression (10). In addition to this, his
studies showed quite conclusively that the
cells of the Jensen sarcoma were less resist-
ant to radium than the fibroblasts of normal
tissue. However, it has been shown clini-
cally that there is always a latent period be-
tween the application of the rays and the
death of cells in a body that has been sub-
jected to radiation. This alone, with our
careful study of the biological effect of X-
rays, tends to make it seem more logical
that the removal of the lipoid solvent from
the tissue irradiated is the process by which
the malignant tissue is destroyed. Studies
have not revealed whether the lipoid solvent

is removed more easily from malignant tis-
sue than from normal tissue. However, our
studies and others make it seem quite evi-
dent that there is a less amount of lipoid
substance in cancer tissue than in normal
tissue. There is a greater amount of the
water-soluble stimulating substance in the
cancer cell, and this would explain the ap-
parent selectivity of radiant energy on ma-
lignant tissue. It has been demonstrated *in
vitro* that an increase in cell stimulus to a
high concentration will cause death of the
cell, and immediate death must be due to
the increase of this water-soluble stimulus.
However, more complete studies must be
made to compare further the circumstances
as they take place in the culture tube and in
the body. No doubt, there is more of the
water-soluble element in the body available
as it is destroyed in a local area, and it is
apparently interchanged from one area to
another, but at this time it seems that the
taking up of the fat-soluble element of the
cell is a more complex process and is not ac-
complished so readily, nor does it seem as
possible to replace it in the cell.

EXPERIMENTAL OBSERVATIONS

In these studies the white rat, varying in
weight from 60 to 130 grams at the begin-
ning of the experiment, has been used. The
main criterion used in a study of these ef-
fects has been the weight curves and the
changes in length of life, as well as the ef-
fect on the litter-bearing properties of the
animals.

Throughout all of these experiments the
following X-ray dosage factors were em-
ployed:

The *intensity effect* of the X-ray beam
in roentgen units was, respectively, 22.6
r per minute in air without back-scattering,
and 31.0 r per minute on the skin, including
back-scattering.

The *effective wave length measurement* of
the filtered beam was 0.15 Ångstrom units

(the fraction of radiation passing through 1 mm. of copper).

Potential of 200 K.V. peak. (Spectrographic estimation of the minimum wave length 145 K.V.)

Filtration of ½ mm. Cu.

Focal skin distance of 80 cm.

Transformer, cross-arm type of rectification.

Water-cooled X-ray tube current employed was 25 milliamperes.

The *treatment fields* were limited to 25 cm. square, exposing six animals simultaneously in individual cardboard boxes, except when otherwise noted.

For the greater number of experiments we have used a chemical ration, varying the vitamin content of it by means of substituting Crisco for butter, or *vice versa*, or increasing or decreasing the quantity of these substances, and in some cases adding cod liver oil.

As stated above, it was found early in our experimental work that the increase in the Vitamin A fraction protected to a certain extent against the toxic effects of X-rays. In our early experiments we gave 12 r (10 ma.-min.) twice a week throughout the course of the experiment, and we increased this amount in the following experiments until at the present time we are giving 124 r (100 ma.-min.) and 155 r (125 ma.-min.) to separate series of rats twice a week over a period of time. It was found that with 12 r (10 ma.-min.) the Vitamin B of the diet was supplanted. With dosages above 62 r (50 ma.-min.) the Vitamin A fraction was supplanted. However, when 124 r (100 ma.-min.) was given twice a week the length of life of the animal was shortened on synthetic rations, especially when the Vitamin A fraction of the diet was not increased (11).

Thus, being aware of the fact that dog biscuits, lettuce and other vegetables, corn or wheat, given to animals *ad lib.*, produce a healthy rat, and in the female produce a healthy progeny in good sized litters, it became necessary to devise a method whereby the different concentrations of Vitamin A might be added to this dietary.

Because cod liver oil or its concentrates could not be mixed with the whole dog biscuit, the dog biscuits were ground and given to the animals *ad lib.* in dishes. As a control series, the ground dog biscuit was given *ad lib.* Lettuce and other greens were given twice a week, meat and corn on other days of the week, to the control and experimental series alike.

In the last experiment, in addition to this ration, 0.1 per cent of a cod liver oil concentrate, or 0.5 c.c. per 500 grams of dog biscuits, was given. In the third setup, the same amount of cod liver oil concentrate, and, in addition, 10 grams of Vegex per 500 grams of dog biscuits, was given. In the fourth setup, 3 per cent, or 15 c.c., of Mead's cod liver oil and 10 grams of Vegex, were given. In the fifth setup the Mead's cod liver oil in the same percentage, without the addition of Vegex, was added to the basic ration, while in the sixth setup, the dog biscuits were soaked in cream and given to the rats *ad lib.* The basic ration thus was the ration as given in the first experiment. The animals were placed on these rations for two weeks previous to being exposed to the X-rays, and the same diets were continued throughout the period of the experiment.

In former experiments, with the addition of 3 per cent Mead's cod liver oil to the basic ration, the rats attained an average weight of 200 grams at the end of six months, whereas at the beginning of the experiment they weighed from 50 to 80 grams. The amount of X-rays given to these animals was 124 r (100 ma.-min.) in one series, and 155 r (125 ma.-min.) in the other series. In the case where cream was given instead of cod liver oil, the increase in weight was not so marked, as the average

Gms.

Xray Started

Xray Ended

155 r (125 ma.-min.) X-rays
215 K.V. peak voltage
0.5 mm. Cu. 0.15 Angstrom unit
80 cm. F.S.D.

Cage I

Cage II

155 r (125 ma.-min.) X-rays
215 K.V. peak voltage
0.5 mm. Cu, 0.15 Ångstrom unit
80 cm. F.S.D.
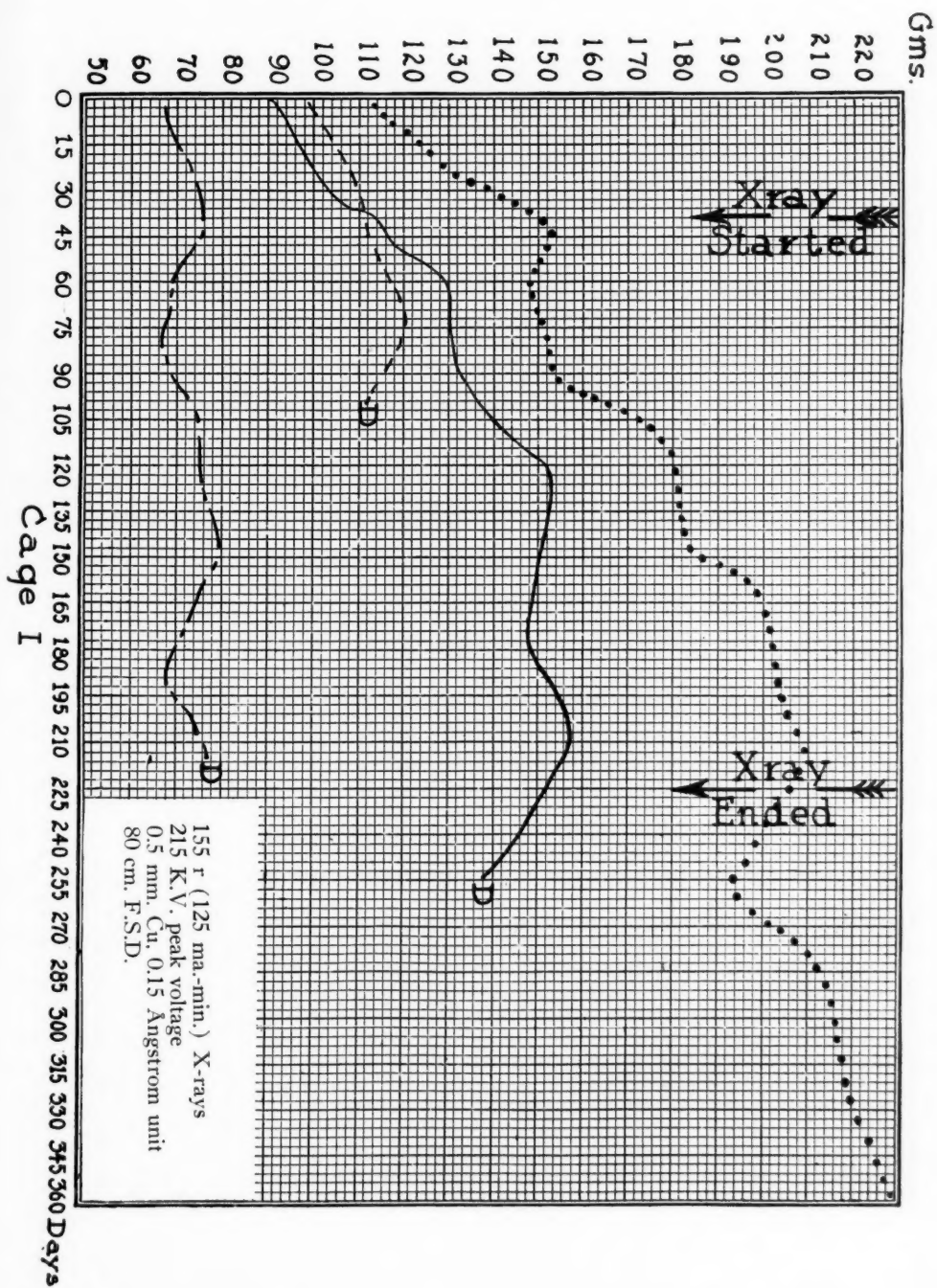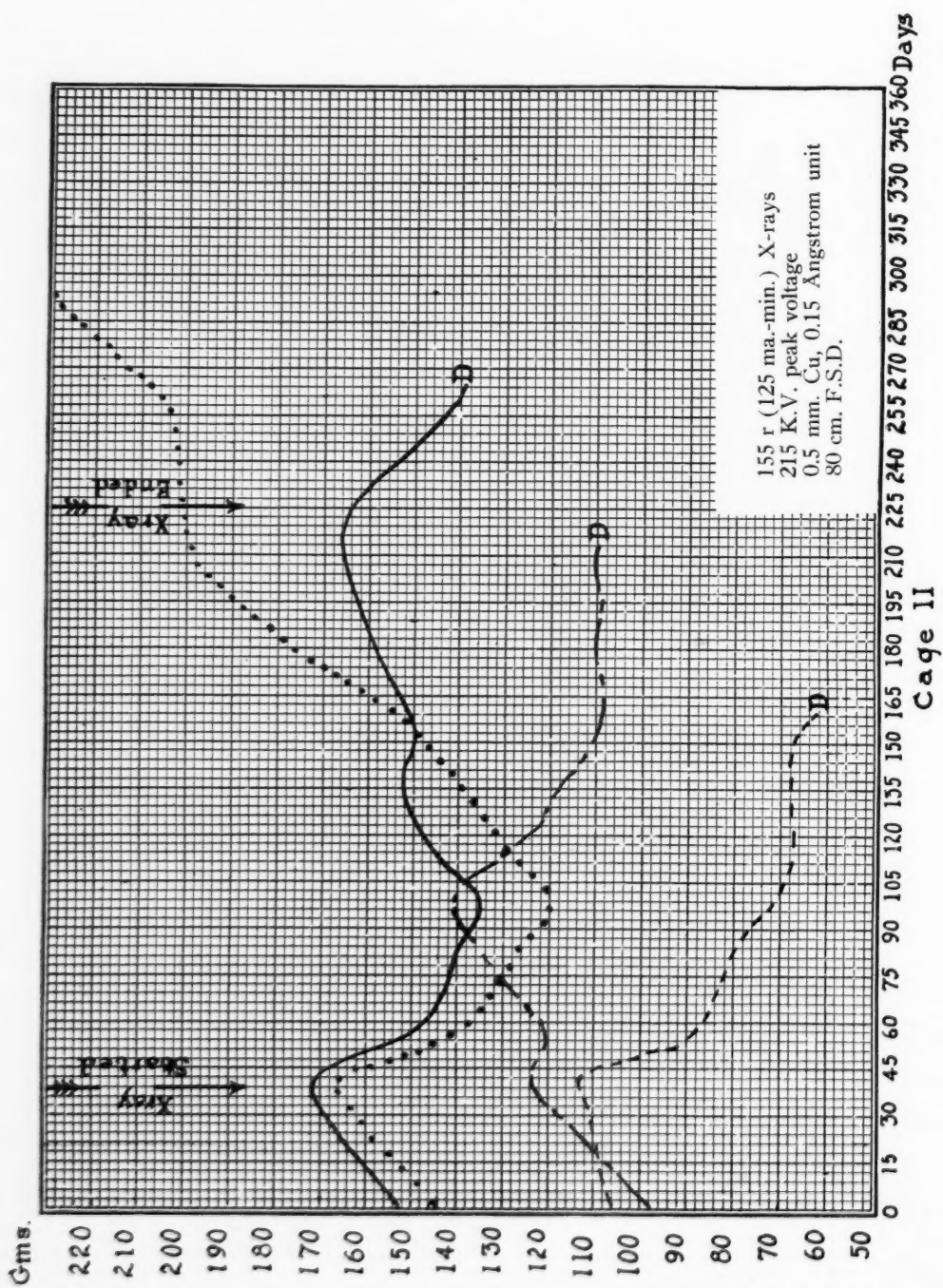
weight at the end of the six-month period was 175 grams, the weight of the animals at the beginning being the same as in the former experiment.

In a series of experiments to determine the effect of changing the constituents in the basic portion, we were unable to find any substance which had any direct bearing on the toxic effect of the X-ray. The animals on the basic ration gained weight for a period of two months, and then remained stationary for a period of from fifteen to thirty days, or in some cases lost weight quite rapidly from the sixty-day period. Upon the addition of cod liver oil to the dietary, there was a gradual increase in weight from the beginning of the experiment, and this continued indefinitely.

In a previous article, Ernst outlined a method of measuring the X-rays in electrostatic e-units, which unit closely approximates the present international r-unit (12). Thus, throughout our experiments we have used the same quality of X-rays, varying only the quantity and determining the different reactions in the body. We contemplate further studies with the less penetrating or softer ray, given over the whole of the body. In the induction of the local X-ray erythema we used a softer ray and varied the dose so as to produce varying degrees of erythema or merely a transient inflammatory reaction. Then, too, we contemplate radiating foodstuffs to determine the effect of different quantities of the ray when administered in this way.

Jorstad had an opportunity recently to review the work of Dr. F. A. Hecker,[2] of Ottumwa, Iowa, who has been making a study of the tissue changes following X-ray burns. The tissue changes in his rats are similar to those Jorstad and Lane observed (13). He modified the procedure in some of his series, in that he introduced a small quantity

of calcium chloride subcutaneously at the time the X-ray was given. The local area in these animals showed more marked malignant change, and there were definite metastases to lymph nodes and other organs of the body. This occurred when calcium chloride was injected into the tissues without inducing the X-ray erythema also. The preliminary report of this work was read before the American Association of Experimental Pathology last April. In each of the metastatic areas one finds deposits of calcium, and Jorstad noted that coal tar was present in metastatic areas in rats in which an area of skin was painted with coal tar, or the tar injected subcutaneously (14).

Quite recently Maisin and François experimented on two groups of mice (15). The first group received a fairly well balanced diet, while the second group received, in addition to this, 5 grams of fresh liver three times a week. All of the mice were painted with tar three times a week for 120 days. At this time cancer was observed in 21.5 per cent of the mice on the liver diet, but in only 4.16 per cent on the control diet. Later observations showed the percentages of metastases were approximately 25 per cent higher in the animals fed with liver. The control mice lived on the average 70 days longer than the others.

It is thought that there is some specific substance in liver which has proved efficient in the treatment of pernicious anemia. In former studies from this laboratory we have referred to the corollary that a diet rich in Vitamin A will also protect against the marked malnutrition of pernicious anemia, and, as has been described above, the high Vitamin A dietary given to animals is more apt to cause the diffusion of coal tar or a similar lipoid solvent throughout the system. Another phenomenon which has been observed in studies from this laboratory, is that not only is the lipoid solvent more apt to be diffused throughout the system in an

animal on a high Vitamin A dietary, but other fatty changes occur in this animal. When we used a lipoid solvent which did not have the marked viscosity of coal tar, or if we mixed coal tar with a less viscid lipoid solvent, such as Mazola oil, we noted that within 60 days or earlier, these rats which had been doing very well up to that time developed a marked fatty infiltration of the liver. The liver, of course, is the largest storehouse of fat in the body—a fat which is quite easily available for use by the body.

It is not unreasonable to assume that one and the same group of substances contained in body fat is responsible for this entire mechanism. That calcium chloride may disturb this same mechanism, or that liver may disturb the same mechanism, or that a lipoid solvent may be responsible for such a disturbance, points to this assumption. It does not mean that we are dealing with a number of substances, because all of them are closely allied with the metabolism as affected by Vitamin A, especially when one considers Vitamin D as a part of Vitamin A, or that the marked changes induced in the infant or growing child by Vitamin D must have a counterpart in the older individual, the change in that case being produced by Vitamin A.

DISCUSSION

In a study of the weights listed as of different intervals of time during the course of several experiments, a number of findings are of interest. In Experiment No. 60, the only rats of 75 to 100 grams weight at the beginning of the experiment that survived the six-month period were those fed on a stock ration to which had been added 3 per cent by weight of cod liver oil. These rats gained weight throughout the period of observation.

In Experiment No. 61, the animals fed Ration V, in which wheat was substituted for meat, and Ration IV, in which cream was substituted for meat, showed the most marked gain in weight and survived for the longer period of time. These rats received 155 r (125 ma.-min.) of X-rays twice a week instead of 124 r (100 ma.-min.) of X-rays, as given in Experiment No. 60. We have published data in previous papers (*loc. cit.*) showing the effect of 124 r (100 ma.-min.) of X-rays on the weight curve of the rat on different dietaries. It is interesting to note that the increase in weight during the first or second month is not so marked in Experiment No. 61 as in Experiment No. 60. For comparison, note also Rations I and V, in Experiment No. 60, and Rations IV and V, in Experiment No. 61. The curves plotted from weekly readings of the weights obtained with these rations show the definite undulations, which become more marked as the X-ray administrations increase in number. These undulations follow the first transient decline in weight noted directly after the first X-ray dose. The extent of the declinations becomes less accentuated as the experiment progresses, and is less marked in the animals given the rations which withstood the X-rays best as determined by gain in weight and length of life. It is possible that this may indicate the development of a resistance to X-ray as the result of repeated exposures. Some investigators may view this as evidence that the X-ray plays the part of an antigen in the body, setting free cytolytic ferments, which, in turn, cause the liberation of immune bodies in the nature of anti-ferments. The clinical results obtained with the X-ray in the treatment of erysipelas are difficult to explain on any other basis than that of antibody or tissue enzyme liberation. The setting up of tissue enzymes is a more plausible assumption than that of a direct bacteriolysis. It has been quite definitely shown by a number of workers in the past few years that fat-splitting ferments are important factors in the immune reactions in the body.

155 r (125 ma.-min.) X-rays
215 K.V., 0.5 mm. Cu,
80 cm. F.S.D.

155 r (125 ma.-min.) X-rays
215 K.V. peak voltage
0.5 mm. Cu, 0.15 Ångstrom unit
80 cm. F.S.D.

Cage IV

* Intercurrent Infection

0 15 30 45 60 75 90 105 120 135 150 165 180 195 210 225 240 255 270 285 300 315 330 345 360 Days

Gms.
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50

Xray Started

Xray Ended
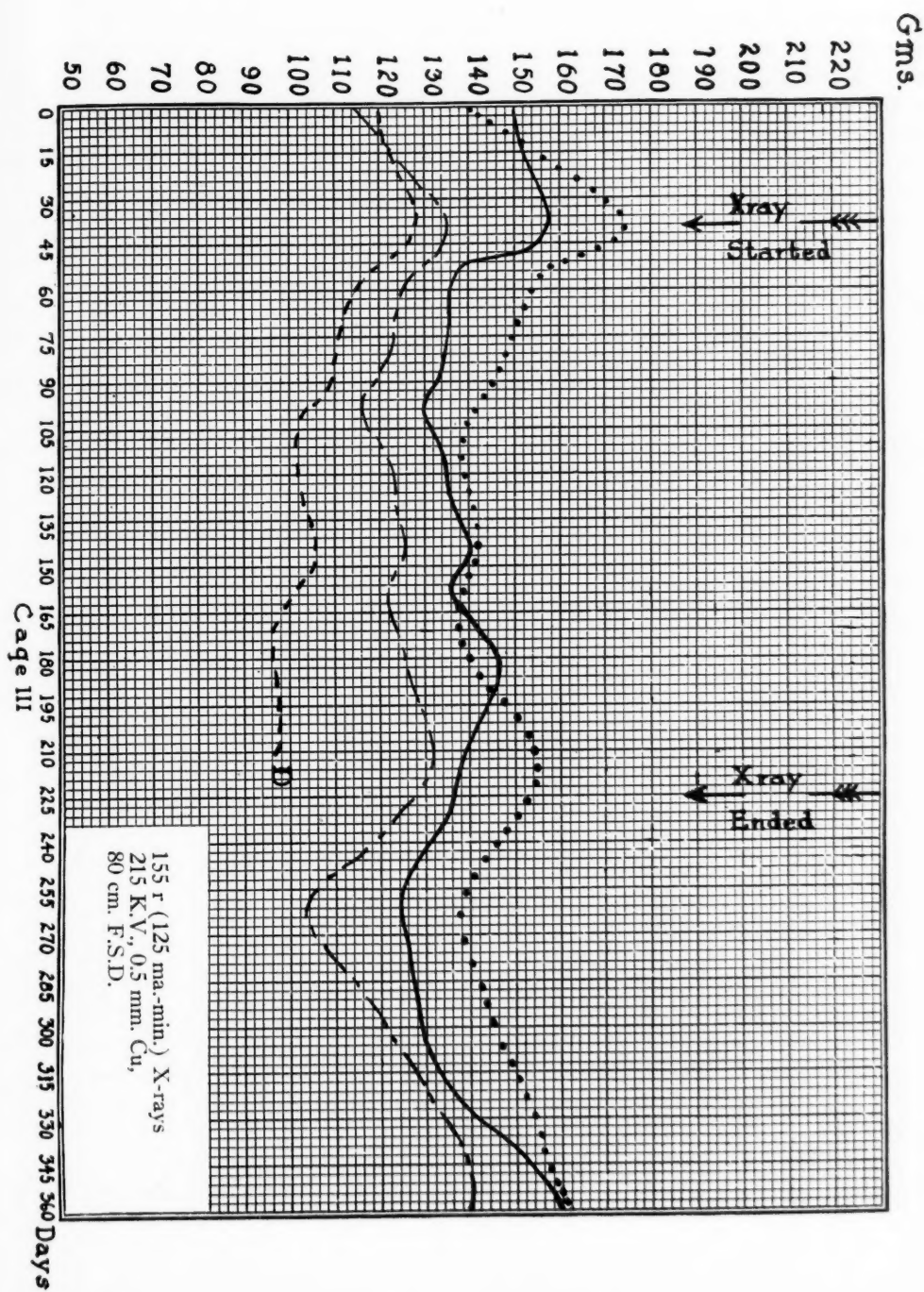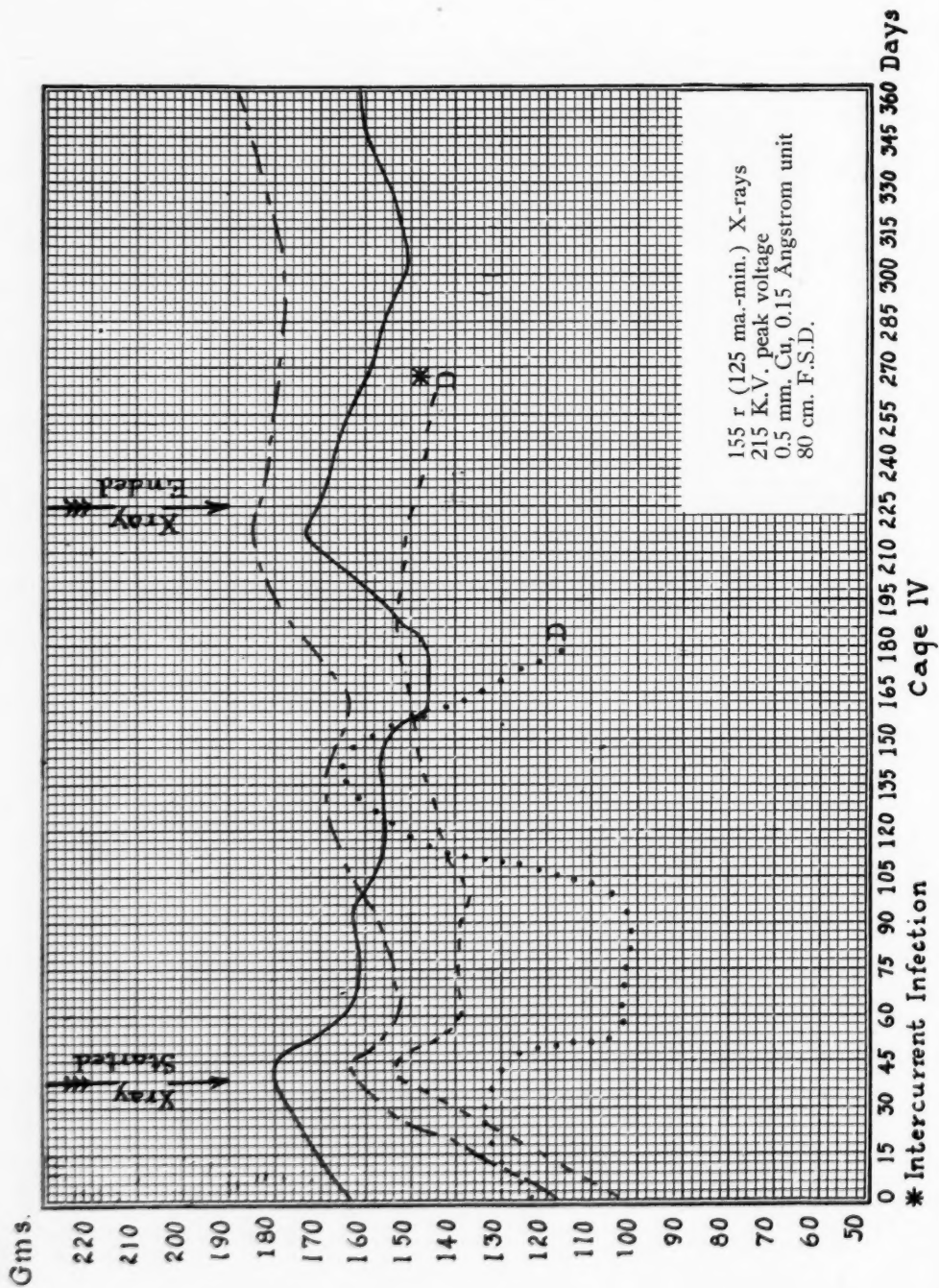
EXPERIMENT NO. 60

124 r (100 ma.-min.) X-rays twice a week for duration of experiment

Ration	Weights beginning	One month later	Two months later	Six months later
I	80 gm. 102 gm. 96 gm. 103 gm.	120 gm. 120 gm. 120 gm. 130 gm.	120 gm. 110 gm. 112 gm. 130 gm.	All dead at 90 days
II	101 gm. 106 gm. 81 gm. 72 gm.	114 gm. 119 gm. 104 gm. 95 gm.	94 gm. 130 gm. 98 gm. 80 gm.	All dead at 85 days
III	91 gm. 80 gm. 96 gm. 104 gm.	119 gm. 99 gm. 105 gm. 134 gm.	120 gm. 106 gm. 92 gm. 130 gm.	All dead at 70 days
IV	80 gm. 90 gm. 100 gm. 82 gm.	100 gm. 120 gm. 125 gm. 103 gm.	104 gm. 108 gm. 120 gm. 112 gm.	All dead at 90 days
V	78 gm. 79 gm. 80 gm. 86 gm.	103 gm. 110 gm. 104 gm. 136 gm.	150 gm. 170 gm. 150 gm. 175 gm.	165 gm. 200 gm. 175 gm. 210 gm.

EXPERIMENT NO. 61

155 r (125 ma.-min.) X-rays twice a week for duration of experiment

Ration	Weights beginning	One month later	Two months later	Six months later
I	94 gm. 78 gm. 102 gm. 108 gm.	102 gm. 88 gm. 110 gm. 117 gm.	112 gm. 100 gm. 116 gm. 124 gm.	All dead at from 100 to 140 days
II	106 gm. 82 gm. 78 gm. 95 gm.	114 gm. 89 gm. 85 gm. 102 gm.	118 gm. 92 gm. 94 gm. 105 gm.	All dead at from 70 to 90 days
III	92 gm. 81 gm. 100 gm. 79 gm.	104 gm. 94 gm. 109 gm. 86 gm.	116 gm. 108 gm. 132 gm. 100 gm.	All dead at 140 days
IV	116 gm. 122 gm. 94 gm. 88 gm.	124 gm. 131 gm. 102 gm. 97 gm.	133 gm. 141 gm. 112 gm. 107 gm.	All dead at 145 days
V	106 gm. 118 gm. 96 gm. 84 gm.	117 gm. 128 gm. 118 gm. 117 gm.	136 gm. 135 gm. 127 gm. 127 gm.	All dead at from 110 to 140 days

Thus, with the smaller doses of X-rays which induce a transitory change in tissue, it may be possible that the change is mainly the setting free of ferments. The actual measurements we obtained in former experiments as to the liberation of Vitamin B or A, depending on the quantity of X-ray given, do not refute but rather tend to substantiate this idea. The larger doses of X-rays causing a definite destruction of protoplasm do more than cause a liberation of ferments, however. The tissue destruction is permanent.

The gross observations of the animals on Ration II in Experiment No. 61 were more striking than the weight curves, as these animals did very badly, while the animals on Ration V in the same experiment did not show the loss of weight or lack in gain, diarrhea, and inactivity such as were present in the former setup. This was not due to a smaller consumption of wheat on account

124 r (100 ma.-min.) X-rays twice a week for duration of experiment

Ration	Weights at beginning	One month later	Two months later	Six months later
I	130 gm. 143 gm. 92 gm. 61 gm.	135 gm. 143 gm. 101 gm. 67 gm.	134 gm. 142 gm. 126 gm. 85 gm.	142 gm. 155 gm. 140 gm. 114 gm.
II	135 gm. 113 gm. 68 gm. 89 gm.	138 gm. 133 gm. 80 gm. 89 gm.	140 gm. 132 gm. 87 gm. 90 gm.	D D D D
III	134 gm. 116 gm. 60 gm. 58 gm.	145 gm. 130 gm. 77 gm. 67 gm.	154 gm. 140 gm. 95 gm. 93 gm.	160 gm. 152 gm. 110 gm. 115 gm.
IV	155 gm. 143 gm. 56 gm. 60 gm.	166 gm. 136 gm. 86 gm. 82 gm.	180 gm. 139 gm. 122 gm. 106 gm.	165 gm. 138 gm. 123 gm. 96 gm.
V	148 gm. 177 gm. 63 gm. 68 gm.	170 gm. 190 gm. 100 gm. 102 gm.	173 gm. 200 gm. 123 gm. 128 gm.	173 gm. 200 gm. 150 gm. 190 gm.
VI	67 gm. 148 gm. 78 gm. 72 gm.	69 gm. 160 gm. 127 gm. 120 gm.	69 gm. 175 gm. 156 gm. 148 gm.	79 gm. 172 gm. 200 gm. 186 gm.

of the availability of carrots and lettuce, as the quantity consumed in each experiment was practically the same. Then, too, this contrast between animals fed dog biscuits and cracked corn, and animals fed dog biscuits, cracked corn, and vegetables, has not been noted. We have not investigated further the apparent untoward results obtained by using wheat as a substantial part of the ration. We have repeated this setup with the same results.

In Experiment No. 62, some of the rations in Experiment No. 61 have been repeated, and 124 r (100 ma.-min.) have been given instead of 155 r (125 ma.-min.). Weights of from 60 to 90 gram rats and of from 120 to 150 gram have been tabulated to note if animals of different age levels respond differently. Aside from the observations noted above, the findings of note here have been the protective action of Ration V, and the similarity of weight curves of the younger and older animals.

As a result of these and former studies, it seemed logical to assume that an increase in the fat-soluble vitamins in a well balanced ration would be most protective against larger dosages of X-rays. It had not been determined, however, whether an increase in the Vitamin B fraction would produce a difference in protectivity in the presence of this increase in Vitamin A. Thus, in Experiment No. 64, the stock ration was used as a basic control ration, and Vitamin B and Vitamin A added as noted in the protocol.

With one exception the results obtained with Ration I in Experiment No. 64 compare favorably with Ration I in Experiment No. 60. This rat received the same dietary and the same amount of X-ray as the remainder of the rats in the cage. This same phenomenon occurred with Ration II in Experiment No. 64, which may be considered a coincidence, as both of these setups have been repeated. It has been noted in previous experiments, not alone in this series, that occasionally one animal in a group will respond, differently from the others. Such observations have been recorded clinically also and have been interpreted on the basis of a difference in individual reactivity. This is especially true in radiation therapy.

Cage V

155 r (125 ma.-min.) X-rays
215 K.V. peak voltage
0.5 mm. Cu, 0.15 Ångstrom unit
80 cm. F.S.D.

Cage VI

122 r (125 ma-min.) X-rays
215 K.V. peak voltage
0.5 mm. Cu, 0.15 Ångstrom unit
80 cm. F.S.D.
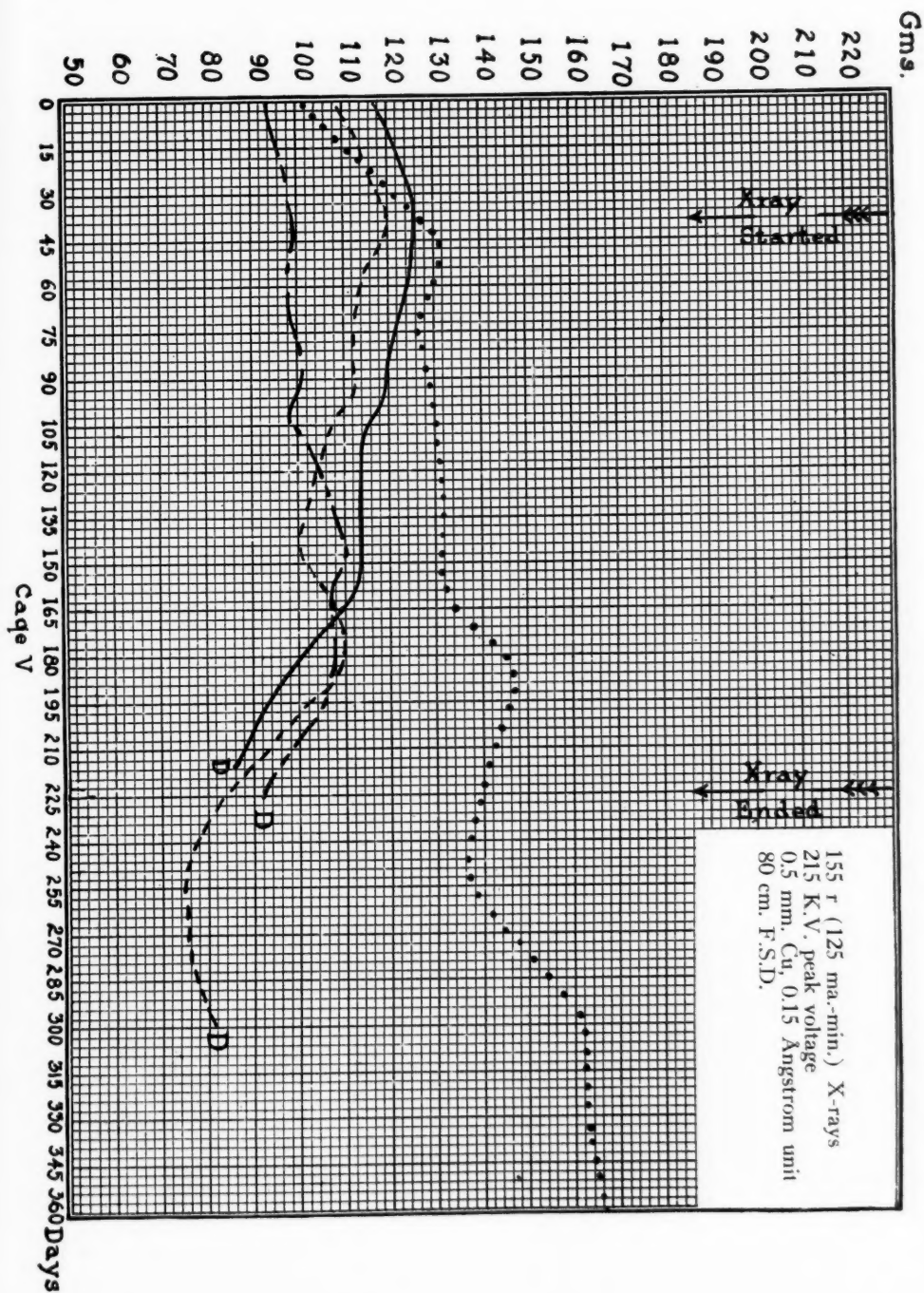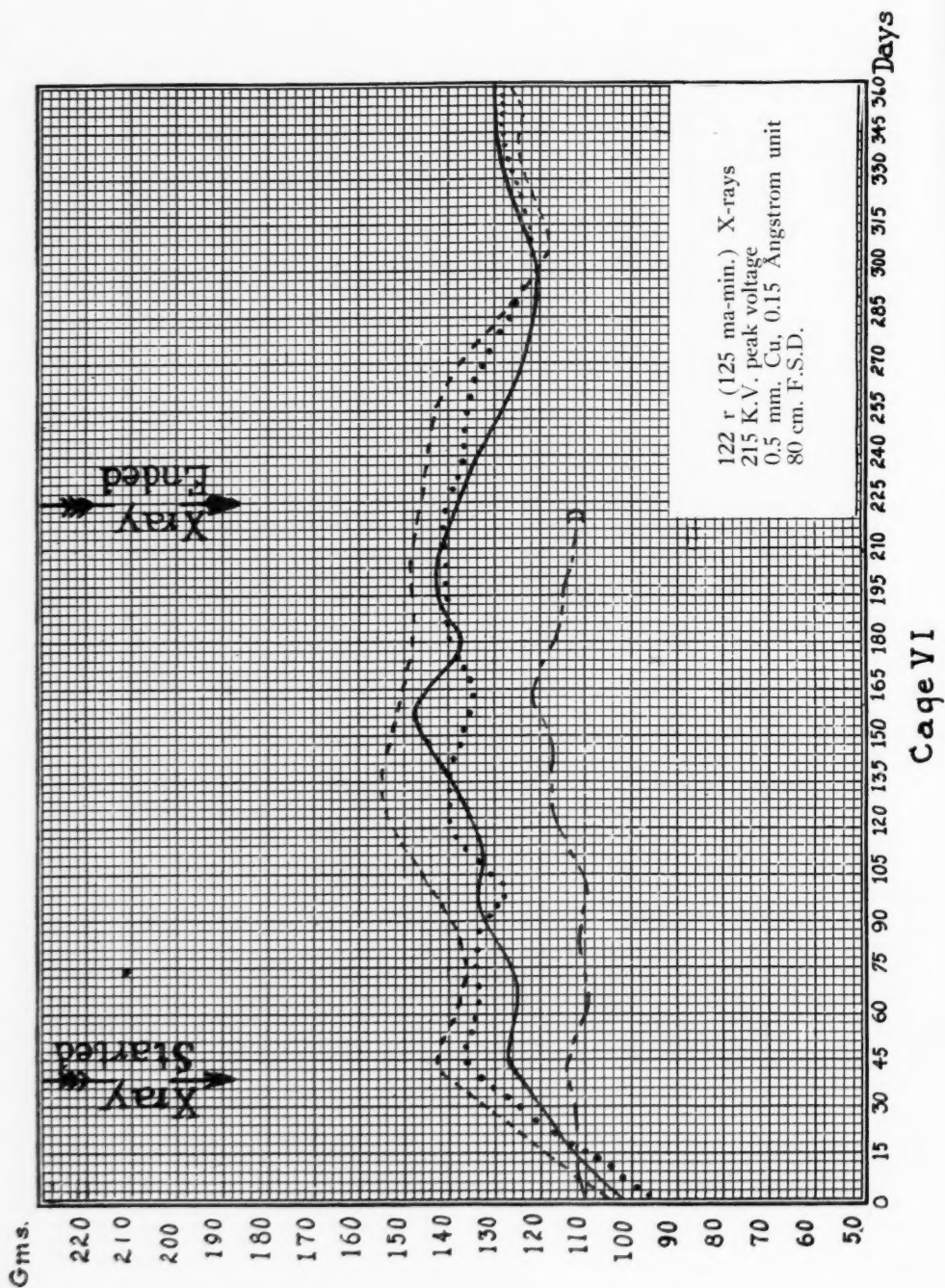
EXPERIMENT NO. 64

155 r (125 ma.-min.) X-rays twice a week for period of six months

Ration	Weight at beginning	One month later	Two months later	Six months later	One year later
I	72 gm.	73 gm.	77 gm.	Dead	
	105 gm.	135 gm.	150 gm.	148 gm.	Dead
	160 gm.	170 gm.	200 gm.	188 gm.	230 gm.
	130 gm.	135 gm.	145 gm.	Dead	
II	175 gm.	135 gm.	150 gm.	170 gm.	Dead
	170 gm.	120 gm.	150 gm.	203 gm.	260 gm.
	125 gm.	140 gm.	110 gm.	110 gm.	Dead
	110 gm.	70 gm.	65 gm.	Dead	
III	130 gm.	120 gm.	100 gm.	105 gm.	Dead
	160 gm.	130 gm.	130 gm.	140 gm.	160 gm.
	140 gm.	120 gm.	120 gm.	130 gm.	175 gm.
	180 gm.	130 gm.	140 gm.	140 gm.	180 gm.
IV	180 gm.	160 gm.	145 gm.	160 gm.	185 gm.
	175 gm	100 gm.	95 gm.	Dead	
	170 gm	160 gm.	160 gm.	180 gm.	190 gm.
	160 gm.	135 gm.	145 gm.	150 gm.	180 gm.
V	100 gm	100 gm.	110 gm.	108 gm.	Dead
	130 gm.	125 gm.	110 gm.	90 gm.	Dead
	120 gm.	110 gm.	105 gm.	80 gm.	Dead
	125 gm.	130 gm.	130 gm.	150 gm.	165 gm.
VI	112 gm.	110 gm.	125 gm.	130 gm.	Dead
	140 gm.	140 gm.	155 gm.	140 gm.	125 gm.
	140 gm.	130 gm.	150 gm.	135 gm.	130 gm.
	130 gm.	130 gm.	150 gm.	125 gm.	125 gm.

There is a difference in the effect of radiation therapy on tumors and there is a difference in effect, or we may say reaction, in different individuals given the same amount of radiation. In comparing the weight curves on Rations III, IV, and VI in Experiment No. 64, it is to be noted that the weight changes are different after X-ray administration is stopped (Charts I to VI). There is a gradual increase in weight after the last decline of the curve following the last X-ray exposure. It is interesting to note that this same finding is true of the remaining rat in Cage 1 and Cage 2 also. The steadily mounting but undulating weight curve is present in each setup. Of the whole series, Ration III is the most protective. In a study of this curve the increase in weight after the last X-ray exposure is practically the same as the increase in weight noted before the X-ray was started. This is to be compared with the weights on Ration VI. Ration IV is practically equally as protective as Ration III. However, when one compares the initial gain in weight before the

X-ray was started, the undulations of the weight curve during the period of X-ray treatment, the period of decline in weight after the X-ray was ended, taking into consideration the loss of one animal at this time, and the less marked gain in weight following this decline, Ration III seems the most protective, even though there was a more marked loss of weight in this series during the period over which X-ray was given. It is interesting that both of these rations contained Vegex in addition to the cod liver oil, and cod liver oil concentrate,[3] respectively. The gross clinical findings and autopsy on these animals show nothing of interest. It is worthy of remark that in this experiment as well as in others rats on a ration to which cream has been added survive and show no marked untoward signs and symptoms under X-ray therapy; they look healthy and are active during the course of the experiment, but they never attain the

weight that is noted in other animals on rich Vitamin A rations.

CONCLUSIONS

1. The white rat withstands relatively large amounts of X-radiation given at bi-weekly intervals over a period of time if cod liver oil is added to a well balanced stock ration.

2. Even though a well balanced ration rich in Vitamin A is protective, the rats do not gain weight as rapidly during the period of X-ray exposures as they do previous to and following this period.

3. Occasional exceptions to this rule are noted.

We wish to take this opportunity to state our appreciation of the special efforts made by Miss G. Boehm in carrying out the laborious routine necessary in numerous dosages of X-ray. We also wish to thank the Barnard Free Skin and Cancer Hospital and the Community Fund of St. Louis, through whose financial assistance it was possible to carry out this work.

PROTOCOL

Experiment No. 60.—*Ration I*, stock ration of dog biscuits, lettuce, cracked corn, meat, and water; *Ration II*, dog biscuits and water; *Ration III*, dog biscuits, meat, and water; *Ration IV*, dog biscuits, meat, lettuce, and water; *Ration V*, dog biscuits with 3 per cent by weight of cod liver oil, meat, lettuce, and water.

Experiment No. 61.—*Ration I*, dog biscuits, cracked corn, and water; *Ration II*, dog biscuits, wheat, and water; *Ration III*, dog biscuits, carrots, lettuce, and water; *Ration IV*, dog biscuits (soaked in cream), lettuce, carrots, and water; *Ration V*, dog biscuits, carrots, lettuce, wheat, and water.

Experiment No. 62.—*Ration I*, dog biscuits, corn, and water; *Ration II*, dog biscuits, wheat, and water; *Ration III*, dog

biscuits, lettuce, carrots, and water; *Ration IV*, dog biscuits, lettuce, carrots, spinach, and water; *Ration V*, dog biscuits (soaked in cream), carrots, spinach, lettuce, and water; *Ration VI*, dog biscuits, carrots, lettuce, spinach, wheat, and water.

Experiment No. 64.—*Ration I*, stock ration, same as Experiments No. 60 and 61; *Ration II*, 0.1 per cent cod liver oil concentrate, or 0.5 c.c. per 500 grams of material added to Ration I; *Ration III*, 2 per cent of Vegex, or 10 grams, added to Ration II; *Ration IV*, 3 per cent of Mead's cod liver oil, or 15 c.c. per 500 grams of material, and 2 per cent of Vegex, or 10 grams, added to Ration I; *Ration V*, 3 per cent of Mead's cod liver oil, or 15 c.c. per 500 grams of material added to Ration I; *Ration VI*, one-quarter pint of cream per 100 grams of material added to Ration I.

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FURTHER STUDIES ON THE SKIN ERYTHEMA WITH COMBINATIONS OF TWO TYPES OF RADIATION[1]

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IT is axiomatic in radiation therapy that the amount of radiation which can be delivered to a given point through one skin portal is strictly limited by the amount the skin will tolerate. With a realization of the need in many cases for larger doses of radiation, have come various efforts to increase this tolerance limit. These have taken two forms: (1) An attempt to find something which could be applied to the skin to "toughen" it, or decrease its sensitivity, and (2) an attempt to vary the dosage technic in some manner so that the skin would permit the use of more radiation. One method of this kind which seemed to give some satisfactory results was to use combinations of different types of radiation in the treatment of the case, rather than to rely on a single type. Clinically it seemed that such combinations were at times more effective, but it is difficult to draw definite conclusions with regard to such a question from clinical evidence alone. In order to obtain an evaluation of the advantage of such a method of treatment two points must be settled: (a) Does the skin actually tolerate more radiation when combinations of different types are used? (b) Does the tumor also tolerate more of the combined radiation, or is there a differential action, so that the combination acts less strongly on normal skin, but at least as strongly on tumor tissues, as any one type alone? This second question is just as important as the first, but is often ignored.

In the present paper it is proposed to answer the first question for a number of combinations of radiations, ranging from hard beta rays through soft and hard X-rays, to gamma rays. Some of this material has already been published (1, 2), but it seems advisable to collect it all together here. The second question will not be touched upon in this paper, but we wish to emphasize the fact that until it is answered the method of treatment with combinations of different radiations has not been proved more efficient than the use of a single type of rays.

The method of measuring the amount of radiation used is obviously very important. The use of any physical scheme might introduce a grave source of error, for it has not been shown that the skin erythema dose is independent of the quality when the quantity of radiation is measured by any of the various physical or biological units which have been suggested. We have avoided any such difficulty by the simple device of measuring the quantity for each type of radiation by the very effect we are studying. That is, in each case, keeping the output of the source of radiation constant, we have determined the time necessary to produce the threshold erythema.[2] Then half the dose will be given in half the time, and so on. The question of variation in effect with duration of the irradiation does not enter for such differences of time as exist between a half and a full dose of any type of radiation used in these experiments. The various sources were so arranged that it took about the same length of time for each to produce an erythema. This method of determining the quantities of radiation used makes unnecessary the use of any measur-

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[2] The threshold erythema is the dose which, in 80 per cent of all cases treated, produces a faint reddening or bronzing of the skin two or three weeks after irradiation, and in the other 20 per cent no visible effect. By observing a large number of cases it is possible to determine this dose with much greater accuracy than one producing a definite color reaction. Fifty to sixty tests were made with each type of radiation in determining its threshold erythema dose.

ing instrument other than a timepiece, except for the purpose of checking the constancy of the output of radiation.

Five types of radiation were used, two at a time, in various combinations. They will be described in detail, and afterward referred to by their numbers.

I. *Gamma rays.*—(*a*) In the first series of experiments involving gamma rays the source was a radon tube having a filter of 0.5 mm. silver, 1.0 mm. brass, and 2.4 mm. rubber—the standard gamma-ray filter in use at the Memorial Hospital at that time. This was used at distances of 5 and 10 mm. from the skin. The threshold erythema was produced by 64 mc.-hr. at 5 mm.; 290[3] mc.-hr. at 10 mm. (*b*) For later series of gamma-ray experiments, the source was two tubes of radium sulfate, 20 mm. long and 4 mm. in diameter, placed side by side in a holder of balsa wood and hard rubber, the filter being 0.5 mm. platinum and 9 mm. of rubber and wood. In this case the radium-to-skin distance measured from the center of the tube was 10 millimeters. Two hundred ninety-five[3] mg.-hr. were required to produce the threshold erythema under these conditions.

II. *Radium radiation predominantly beta.*—The source was a radon tube filtered by 0.16 mm. brass and 1.2 mm. rubber. This filter removed the softest rays and left a mixture consisting of about 67 per cent beta rays and 33 per cent gamma rays.[4]

This was used at 10 and 40 mm. from the skin, the threshold erythema being produced by 8 mc.-hr. and 115 mc.-hr., respectively.

III. *Hard X-rays.*—The source was a constant potential machine equipped with kenetrons and condensers, and the output was very constant. The specifications of the radiation were 165 K.V. (measured spectrographically), 3 ma., 0.4 mm. copper and 1 mm. aluminum filter, 50 cm. target-skin distance, 3×3 cm. area on skin, 295 ma.-min. required to produce threshold erythema.

IV. *Soft X-rays.*—The source was a mechanical rectifier outfit providing radiation at 30 K.V. (approximately), 4 ma., 1 mm., aluminum filter, 15 cm. target-skin distance, 3×3 cm. area on skin, 150 ma.-min. required to produce threshold erythema. The output of this machine was not so constant as that of the kenetron apparatus, but it was carefully controlled by ionization measurements and due allowance made for small variations.

V. *Ultra-violet rays.*—The source was a quartz mercury arc operated at 80 volts and 3.6 amperes. With a 50 inch lamp-to-skin distance a threshold erythema was produced for a 5×5 cm. area in 16 minutes. This was a well-seasoned lamp. It was necessary to run it for about half an hour each time before it attained a steady output, but after that it was quite constant.

The combinations investigated were I and II, I and III, I and IV, and IV and V, equal parts of the two radiations under consideration always being used.

The method of procedure in every series of experiments was the same. First the threshold erythema dose for each individual radiation was determined. The method of doing this has been published in detail (2) and will not be repeated here. For the combination, using one of the two types, from 40 to 70 per cent of an erythema dose was

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[3]We wish to call attention to the close agreement in these two threshold erythema doses obtained by two observers independently. It is often stated that any use of skin erythema as a quantitative standard is of little value because it is impossible to observe the reaction with sufficient accuracy. This is doubtless true when a definite degree of reddening is considered. The threshold erythema which we have used is not open to this objection. Our argument on this point is well supported by the evidence here shown. For the first series of these doses, determined some years ago, the tests were made by one of us (E. H. Q.). For the second, obtained during the past year, the observations were made by the other (G. T. P.). The applicators were not identical, but the radium-to-skin distance was the same and the radiating area and filter were practically equivalent. Hence the threshold dose should be the same for both. And the ones experimentally determined as just stated, agree within less than 2 per cent.

[4]The reason for using a small filter in addition to the bare glass tube was to avoid errors due to small differences in the thickness of the glass walls of the radon tubes. Such variations would produce large variations in the amounts of very soft radiations transmitted. Therefore it seemed better to use a filter which would eliminate this very soft radiation in any case.

given to the right leg, just above the knee. The corresponding dose of the second type was administered to the same area immediately afterward. Then a different dose of the second type was used on the left leg,

It may be said at once that in no case did it make any difference which radiation was used first. At least ten patients were tested with each quantity of combined radiation, and the percentage of positive results for

Percentage of combined radiation administered.
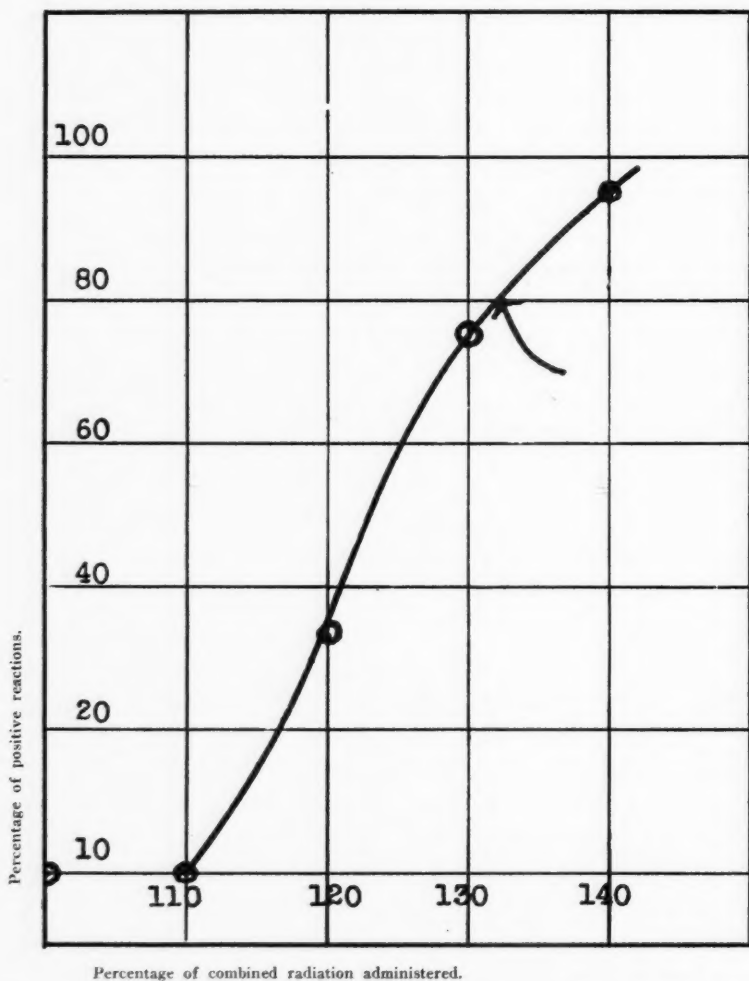
Fig. 1. Curve for determining threshold erythema dose for a combination of equal parts of gamma rays and soft X-rays.

followed immediately by the corresponding dose of the first type. Thus for every combination two complete series of tests were made, in either one of which the order of the irradiations was the reverse of the other.

this amount observed. Figure 1 shows the method of plotting these percentages and the corresponding doses. The data of this figure are for the combination I and IV. From the curve the quantity which gives 80

TABLE I
AMOUNTS OF RADIATION NECESSARY TO PRODUCE THRESHOLD ERYTHEMA:
VARIOUS TYPES OF RAYS USED SINGLY AND IN COMBINATIONS OF
EQUAL PARTS OF TWO

For Any Single Type, 100 Per Cent of the Dose Produces the Erythema	
Combinations	Percentage of Combined Radiation Required
Beta and Gamma Rays (Both Sources 10 mm. from Skin)	133
Beta and Gamma Rays (Gamma Source 5 mm., Beta 40 mm. from Skin)	135
Gamma Rays and Hard X-rays	133
Gamma Rays and Soft X-rays	132
Soft X-rays and Ultra-violet Rays	More than 150

per cent of positive reactions can be read immediately—in this case, 132. That is, for this particular combination it requires 32 per cent more radiation to produce the threshold erythema than for either component alone. Table I shows the required doses for the various combinations tested.

From these data it is evident that, for all the combinations tested, it takes one-third more of the combined radiation to produce the threshold erythema than for any single type. This is rather surprising. There is no reason for expecting that combinations of such widely different types of radiation should agree in such a manner. In fact, such perfect agreement is probably fortuitous, although there is no doubt regarding the actual increase. A study of the errors which might occur in such experiments has already been published (2) and need not be repeated. The conclusion is that the error in determining any one threshold erythema dose is not more than 6 per cent. Making due allowance for such possible errors, it is still apparent from the table that for the four combinations of radium and X-radiation studied there is an actual increase in the quantity of radiation necessary to produce the observed reaction, and that this increase is practically the same for all combinations, namely, about one-third of the dose.

The erythema and pigmentation are visible evidences of phenomena occurring in fairly superficial layers of tissue. David and Gabriel (3) and Pohle (4) studied capillary changes after irradiation by means of a skin microscope. Phenomena thus visible probably occur within the first 2 millimeters of tissue. The pigment cells, to which the visible tanning is to be attributed, lie in the dermis or epidermis. They are not more than 2 millimeters below the surface in the skin of the thigh, and probably less. It is likely that changes in underlying tissues have some effect on capillary or pigment cell reactions, but it is hardly probable that anything deeper than 1 centimeter would be of any importance in this connection. We have, therefore, studied the distributions of these radiations in the first centimeter of tissue to see if we could find therein an explanation of the increased tolerance of the skin to the combined treatments.

In combination No. 1, with beta and gamma ray sources at the same distance from the skin, it is evident that the distribution of the two types of rays would be very different, and that of the combination quite different from either. If the distance of any applicator from the skin is changed, it is obvious that the distribution of the radiation in the tissue will be changed also. Increasing the distance, of course, will have the effect of increasing the percentage depth dose, while decreasing the distance will have the reverse effect. Therefore, if the gamma ray applicator is moved closer to the skin,

TABLE II
DISTRIBUTION OF VARIOUS TYPES OF RADIATION IN FIRST CENTIMETER
OF TISSUE

Depth in Tissue mm.	Percentage of Radiation Delivered at Depth					
	I	II	III	IV	V	VI
	Gamma Rays at 10 mm.	Gamma Rays at 5 mm.	Beta Rays at 10 mm.	Beta Rays at 40 mm.	X-rays Hard	X-rays Soft
0	100	100	100	100	100	100
1	82	75	62	70	100	97
2	69	57	39	51	99	90
3	57	46	27	39	98	85
5	42	30	14	25	97	70
7	31	19	8	19	95	54
10	24	14	6	14	93	20

and the beta ray one farther away, there will be found pairs of distances for which the distributions for the two will be nearly the same. It is very difficult to make accurate measurements of these depth doses within the first centimeter of tissue, and in the subsequent discussion it must be borne in mind that the values given are not exact. However, no conclusions will be drawn which might be invalidated by more accurate information on this matter. Within the limits of our measurements it was found that when the gamma ray source was used at a distance of 5 mm. from the skin, and the beta ray source at 40 mm., the distribution of the two types was approximately the same. Accordingly the experiment was repeated with these distances—combination No. 2 of Table I. The result obtained was identical with the first. That is, for these two types of radiation, whether the sources are at the same distance or at such distances that the distribution of radiation in the first centimeter is substantially the same, it requires one-third more of a half-and-half combination of the two to produce an erythema than of either one alone.

In the third combination the distributions were different again, but in a direction the reverse of the first case. That is, in the first series a greater percentage of the harder radiation reached a depth of 1 cm. in the tissue, while in the third a greater percentage of softer rays reached this depth (due to the greater target-skin distance). Yet here again the same increase in threshold erythema dose for the combination was found. A similar situation was found in the fourth combination. In this case, as in all the others, the dose for the combination was one-third more than for either radiation alone.

Table II shows the distribution of these various types of radiation in the first centimeter of tissue, as determined by ionization measurements.

It must be remembered, however, that the quantities of radiation necessary to produce these erythemas were equal not from the point of view of ionization measurements, but from that of the skin reaction. This reaction does not occur on the surface of the skin, but at some finite depth—or depths —within it. It is doubtless not a simple reaction, but a summation of several different effects upon several different types of cells. However, for the present, we may assume that, whatever effects are summed, they become evident at the level of the pigment cells, and that these are at an average depth of 2 mm. in the skin. That is, the level at which all the radiations deliver 100 per cent should not be at the surface, but at a depth of 2 millimeters. In this case the values given in Table II would not represent the effective distribution, but this would be more closely approximated by those of Table III. However, this does not at all alter

TABLE III

DISTRIBUTION OF VARIOUS TYPES OF RADIATION IN FIRST CENTIMETER OF
TISSUE—ON ASSUMPTION THAT EQUAL AMOUNTS ARE DELIVERED
AT A DEPTH OF 2 MILLIMETERS

Depth in Tissue mm.	Percentage of Radiation Delivered at Depth					
	I	II	III	IV	V	VI
	Gamma Rays at 10 mm.	Gamma Rays at 5 mm.	Beta Rays at 10 mm.	Beta Rays at 40 mm.	X-rays Hard	X-rays Soft
0	145	175	260	195	101	111
1	120	130	160	140	101	108
2	100	100	100	100	100	100
3	83	81	67	77	99	94
5	61	53	36	49	98	78
7	45	33	21	37	94	50
10	35	25	15	27	92	22

the fact that it takes one-third more of any combination to produce the erythema than of either component of the combination.

There seems to be no physical explanation of this phenomenon. We have estimated the quantity of radiation delivered at different levels in the first centimeter of tissue by 135 per cent of the combinations tested, in comparison with that delivered by 100 per cent of the individual components, with the results shown in Table IV. In this table the first column specifies the individual radiation, the second gives the percentage arriving at the stated depth, if 100 per cent arrives at a depth of 2 millimeters. The third gives two-thirds of this value, which is the quantity of that type of radiation used in the combination. In the fourth column is the total amount of radiation from the combination indicated. The fifth and sixth columns show the ratios of the amount of combined radiation to that of gamma alone (which occurs in every combination) and to that of the second radiation of the pair, respectively. From these two columns it is evident that the amount of radiation delivered by the combination at any level within the first centimeter of tissue is always considerably more than that delivered by the less penetrating of the two components, and equal to or more than that delivered by the other, within the limits of experimental error. In other words, at any level within the

first centimeter of tissue, there is definitely more radiation delivered by 135 per cent of any of the combinations studied than by 100 per cent of either component of that combination.

The actual tissue change which occurs, however, is probably not a simple reaction on pigment cells at a certain level in tissue, as we have supposed, but something much more complicated. Miescher (5) in an extensive study of radiation effects on skin, describes several varieties of cell change which occur. Different types of cell are affected in different ways. These reactions may be due to effects of radiation on different parts of the cell, or of different types of radiation on the same part. The observed skin erythema is the visible evidence of the summation of all these effects, and this visible effect may be reached by various summations. Evidently, then, the reaction for the combination may be really quite different from that produced by the single radiations. In view of the data of Table IV, some such interpretation of the phenomenon seems necessary. Definite information on the matter could not be obtained without extensive microscopic studies of irradiated skin.

It appears, from the evidence presented thus far, that the increased tolerance of the skin to combined radiations is real, and not based on any failure to interpret physical

TABLE IV

QUANTITIES OF RADIATION REACHING DIFFERENT DEPTHS IN TISSUE FOR
DIFFERENT TYPES OF RADIATIONS USED SINGLY OR IN COMBINATIONS
OF EQUAL PARTS OF TWO TYPES

Radiation	Per Cent at Depth for 100 Per Cent Dose	Per Cent at Depth for 67 Per Cent Dose	Per Cent at Depth for Combination	Ratio % for Comb. ——— % for Gamma	Ratio % for Comb. ——— % for Beta or X-rays
2 Millimeter Depth					
All types	100	67	134	1.34	1.34
5 Millimeter Depth					
Gamma—10 mm. Beta—10 mm.	61 36	41 24	65	1.06	1.81
Gamma—5 mm. Beta—40 mm.	53 49	36 34	70	1.32	1.43
Gamma—10 mm. Hard X-rays	61 98	41 66	107	1.76	1.09
Gamma—10 mm. Soft X-rays	61 54	41 36	77	1.26	1.43
10 Millimeter Depth					
Gamma—10 mm. Beta—10 mm.	35 15	24 10	34	0.97	2.26
Gamma—5 mm. Beta—40 mm.	25 27	17 18	35	1.40	1.30
Gamma—10 mm. Hard X-rays	35 92	24 62	86	2.46	0.94
Gamma—10 mm. Soft X-rays	35 22	24 15	39	1.12	1.77

differences. Therefore, as just suggested, a biological explanation must be sought. That is outside the scope of the present paper. We feel that we have answered in the affirmative the first question propounded—"Does the skin actually tolerate more radiation when combinations of different types are used?"

We have found little information in the literature on careful observations of skin reactions with combined radiations, except in the case of X-rays and ultra-violet rays, which we will consider later. Widmann and Weatherwax (6) report observations on 217 cases treated clinically with combinations of two types of X-rays or with gamma rays and X-rays. They found that it required amounts varying from 130 to 155 per cent of the combinations to produce erythemas. The reddening they observe is more intense than our threshold erythema,

and their doses are determined by ionization measurements rather than by the erythema itself, so that it is not possible to compare their results directly with ours. However, their data offer a qualitative confirmation of our finding of increased skin tolerance with combined radiations.

As we stated at the beginning of this paper, the question of the advantage of using combined radiations is only half answered when we have found that the skin will actually tolerate more radiation when it is administered in this manner. It is also necessary to know if the tumor will tolerate more. We have no information on this subject. It appears that the erythema is a complex reaction, due to several effects on several kinds of cells. If the tumor reaction is also complex, we might expect it to act in a similar way to the skin. If, on the other hand, it is a simpler phenomenon, then it

might be expected to respond to the combination as to an actually increased dose of radiation. The question is one which can be settled only by extensive biological and clinical research.

Up to this point we have not discussed the results of our experiments with ultra-violet radiation. This is for two reasons. A glance at Table I will show that this combination did not give the same results as all the others. Moreover, we know very little about the absorption of this radiation in the tissues, and could not include it in any comparisons. As a matter of fact, when we included this combination in our series we were conscious that we were entering an entirely different field, but we were interested to see if a radiation so very different from the penetrating types already studied could follow the same law. When we found that, instead of obtaining our erythema with an increase of one-third in the dose, there was no visible effect with an increase of one-half, there seemed no immediate reason for going on and finding the actual dose necessary. We have found that the effect of ultra-violet and X-rays combined is different from that of X-rays and radium rays, in that it takes considerably more of this combination to produce an erythema. From a clinical standpoint there would be no advantage in using ultra-violet in deep therapy, in such combinations as we have been studying.

It may be of interest, however, to mention certain facts we observed in the course of this study. The individual reactions to ultra-violet rays were found to be much less regular than to radium or X-rays. Although the threshold erythema dose was determined by an average of about seventy-five tests on twelve individuals, there was quite a large range in the actual erythema doses for these persons. For a satisfactory experiment it was necessary to find the erythema dose for each subject separately.

This was not the case with the other types of radiations. In earlier skin erythema experiments (7) we made a practice of testing each patient with a standard erythema dose, and found that over 90 per cent responded to it in a uniform manner.

In administering the combined treatment in this series the question arose as to whether the two types of radiation should be used at the same time, as in all the other combinations, or whether the ultra-violet should be used at the time when the reaction was to be expected from the X-rays—two weeks later. The observed reaction in the case of radium and X-rays is a secondary effect, the primary erythema being ignored in these cases. But ultra-violet radiation does not produce this secondary effect, and if a reaction is to be observed it must be a primary one. From this point of view it would be reasonable to apply the ultra-violet two weeks after the X-rays. But in all the other experiments the two types had been given consecutively, with no lapse of time. Therefore we decided in each patient for this group to give 75 per cent of the X-ray dose to each leg, followed immediately by 75 per cent of the ultra-violet to the right, while the ultra-violet to the left was given two weeks later. Six patients thus treated showed no reaction whatever at any time on either leg. Two others were supposed to be in this series, but in their cases the ultra-violet treatment actually produced a faint erythema, so that their doses of combined radiations were really about 175 per cent. In both of these, the leg which had the X-ray and ultra-violet together showed a faint flush in 24 hours over the whole ultra-violet area, 5 cm. square, with more intense color in the 3 cm. square area which had both radiations. In 48 hours all trace of the reaction was gone, but in two weeks there was a faint bronzed area in the 3 cm. square. The leg which had the X-ray alone at first showed no reaction at any time until the

ultra-violet was used, two weeks later. The day after that a faint erythema from the ultra-violet, with a deeper color in the center area of combined radiation, was observed. A week later—three weeks after the first exposure—both areas of combined radiation showed a faint tanning, but no further evidence of the ultra-violet was visible.

These two cases are too few to warrant any very definite conclusions. However, in view of the fact that it has been stated that ultra-violet rays act as an antidote for excessive X-radiation, the result is interesting. Sampson (8) first published this observation, and a number of clinical reports since have tended to establish the idea. None of these were carefully observed experiments, but rather impressions. However, MacKee and Andrews (9) and Pfahler, Klauder, and Martin (10), in attempting to obtain confirmation of the theory, came out with experimental results which contradicted it. Our two cases indicate that, instead of increasing the resistance of the skin to X-rays, the ultra-violet radiation made it more sensitive, since in these cases three-quarters of an erythema dose of X-rays produced a visible reaction when used in conjunction with a very mild dose of ultra-violet rays.

SUMMARY

It is shown that, for combinations of gamma rays and hard beta rays, gamma rays and soft X-rays, and gamma rays and hard X-rays, in equal parts, it requires one-third more radiation to produce a threshold erythema on human skin than for any of these types used alone.

This increase is real and not based on a misinterpretation of readings of physical instruments. The quantity of radiation was not measured by any instrument, but by its effectiveness in producing the skin erythema.

No physical explanation can be offered for the phenomenon.

In the case of a combination of equal parts of ultra-violet and soft X-rays, the erythema was not produced with an increase of one-half in the dose, under the conditions described.

The authors wish to express their gratitude to Mr. L. Marinelli, who made many of the tests with soft X-rays. They also wish to thank Dr. G. Failla for his interest and helpful suggestions during the course of the work.

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Dr. Francis Carter Wood (New York): This paper of Dr. Quimby's is, I am sorry to say, a rare exception to most of the papers we hear. It is sound both physically and biologically, and she has taken into consideration all possible conditions which apply. Now there cannot be any challenge to her facts; that is obvious. The work has been so painstaking and so thorough that the proof that two erythemas do not amount to 50 and 50 per cent is obvious. Of course, as I pointed out last year, the sum of 50 per cent of a lethal dose of radium and 50 per cent of a lethal dose of X-ray on *Drosophila* eggs comes to 100 per cent, and with extraordinary accuracy. Now that only means that this is true for a very minute group of individual cells, and it gives point to my previous remarks, that the question of an erythema dose is not a matter of physics but of clinical observation. However, it is unquestioned that this 50 and 50 per cent sum is true in tissues for the individual cells, but whether, as Dr. Quimby has carefully pointed out, a tumor will be destroyed more effectively by a combination of 50 per cent and 50 per cent, is not answered by these experiments on isolated eggs of the *Drosophilas*. It is answered only for the individual cell of the tumor, but not the tumor *en masse*, and whether the tumor will be better killed as a gross object by radiation of half X-ray and half radium is again a clinical matter for clinical investigation; it cannot be answered abstractly. It may be that some tumors will disappear by half and half; it may be that the destruction of the tumor does not depend upon the grade of sensitivity of the individual tumor cell. It may be a fact that the very sensitive tumor cells are killed by a 50 plus 50 per cent dose and the very resistant tumor cells require the 135 per cent. That, again, is a purely clinical matter, and no answer can be made except by clinical experiments of

the same type. Remember, these experiments are carried out with materials suspended in the air on very thin gauze, away from all scattering material; that all questions which are involved in the tissues, the type of scatter, the reaction which goes on in the individual protein molecule, the effect on the wave length, the hundred different things we can think of as playing a part— those questions cannot be settled by either the flies' eggs or by the study of the tissues at the present time. Tissue studies on the effect of radiation are, as a matter of fact, very unsatisfactory; they differ with different tissues and different tumors, and some of our tumors are killed by direct action and others by the interference with the circulation which the radiation produces. This is an interesting and valuable paper, which emphasizes the importance of the combination of careful physical and clinical observations. It does not invalidate at all the biological experiments, but only shows that in a complex organism we must be very careful about generalizations. I hope that Dr. Quimby will extend these studies to the very soft and very hard X-rays, making a combination of the two, but in all probability the answer will be the same, because she has used hard X-rays and gamma rays of a fifth—or whatever it may be—of the wave length of the X-ray which she has used, so I think the answer will be the same. I am not astonished that the ultra-violet was not at all consistent: ultra-violet action is molecular and not atomic, and while the mode of killing the cell may be the electrons discharged in the cells, that is something we do not know definitely. It would not be expected that the two reactions would be comparable; one is very superficial, and, also, the erythema with the ultra-violet varies with the pigmentation of the skin and, as you know, a patient easily acquires an immunity or resistance to the ultra-violet.

I hope that in a year or so Dr. Quimby will be able to give an answer from tests on

tumors. The great difficulty with experiments on human tumors is that no human tumor has the same X-ray sensitivity as any other human tumor. That is the advantage in using standard transplanted animal tumors.

DR. W. E. CHAMBERLAIN (San Francisco): Dr. Quimby's work is so careful and scientific as to seem conclusive. Yet, after reading her recent publication on this subject, and hearing this present paper, I am still unconvinced, and I am wondering whether it is possible to carry out such studies by attempts to estimate skin changes, *e.g.*, erythema. Dr. Quimby feels that through the use of many skins, a statistical type of answer has been obtained, of greater value than attempts to read shades of difference on one skin. This is doubtless correct. But in all attempts to determine presence or absence of erythema, it is fundamental that a slight change is recognizable only when it is bordered by sharply demarcated normal (unrayed) skin. An erythema which is readily discernible when sharply contrasted with surrounding protected skin, becomes entirely indistinguishable when situated in the center of a large irradiated area in which the intensity of the dose gradually fades off as one passes from center to margin. Dr. Quimby's radium applications must have given erythemas which faded quite gradually into normal skin, for it is impossible to obtain sharp margins when irradiating with gamma rays. Dr. Quimby now plans to carry out a further study of skin erythema with combinations of two types of rays, this time using hard and soft X-rays. In this study she will have sharply demarcated areas to observe, and I will be very much surprised if she does not find that a 100 per cent erythema effect is obtained when a 50 per cent dose of soft X-ray is added to a 50 per cent dose of hard X-ray.

And I am tempted to ask, "How could it be otherwise?" When one reviews the work of Holthusen, Francis Carter Wood, and others, proving that air ionization and biologic effect are parallel for even grossly different qualities of ray; and when one visualizes the number of different wave lengths that are present in many of the beams that these workers used, it seems quite inevitable that the addition of half doses of two X-ray beams, however dissimilar, must produce exactly one full dose in effect, no more, no less.

DR. G. FAILLA (New York): I think I shall take this opportunity to assure Dr. Wood that I do not question the results which he and Dr. Packard have obtained in their work with *Drosophila* eggs. I believe, on the contrary, that these results are the most accurate which have ever been obtained in work of this sort. However, I do not think that we are justified in generalizing from these results and concluding that all biological effects are independent of the wave length of X-rays.

Mrs. Quimby has presented today some very interesting results, which show that the wave length or combination of wave lengths has a marked effect on the production of skin erythema. She has said (and I agree with her) that there is apparently no *physical* explanation for these results; accordingly they must be accounted for on a biological basis. If, now, we assume with Dr. Wood that biological effects are independent of the wave length, the explanation of Mrs. Quimby's results becomes even more difficult. Personally I have no predilection for one theory or another. I am simply waiting for sufficient experimental evidence before formulating any theory. With all the work on this question which is being done in different laboratories, I believe that it will not be very long before this point is settled to the satisfaction of all concerned.

Dr. Quimby (New York): Dr. Wood has asked me about the relative times of exposure for the different types of radiation. We attempted to adjust our intensities of radiation so that the times would be approximately the same, in order to avoid possible errors from such a variation. It was not possible to do this exactly, but the shortest exposure used was about half an hour and the longest about two hours. This holds for both combined and single types.

I am exceedingly interested in Dr. Chamberlain's results. We have not been able to try the combination of hard and soft X-rays, but I do not believe that the discrepancy between his results and ours is due to inaccuracy in reading the erythemas. It is quite true that it is more difficult to read the radium erythemas than those due to X-rays, but it becomes easier with experience. We tried to eliminate any possible errors in deciding whether erythemas existed. Dr. Pack and I made our observations independently, but our decisions were almost always in accord. I kept the records and knew the doses which had been administered, which might have prejudiced my judgment, but Dr. Pack never knew at the time he examined a patient what the latter's treatment had been. In a few cases it was impossible to be sure of the result, due to some skin condition (blotchiness, hairiness), and these have been omitted from the data. I hope we may be able to repeat Dr. Chamberlain's work and either confirm his results or find out why ours do not agree with his.

A SIMPLE SELF-RECTIFYING GAS X-RAY TUBE

By RALPH W. G. WYCKOFF, Ph.D., and J. B. LAGSDIN

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THIS tube was originally developed because of the need in some biological experiments for a constant and more intense source than is given by the commercially available X-ray tubes. It has proved to be so simple and reliable in everyday operation, however, that in this laboratory it has replaced commercial tubes for the preparation of the different kinds of photographs used in crystal analysis.

Self-rectifying gas tubes have been made familiar to many through the Shearer tube, as manufactured by the firm of Adam Hilger. There is, however, a wide range of tube dimensions over which self-rectification can be obtained. The amount of high voltage current which a tube will pass unilaterally depends upon its total volume, the size of its cathode, the shape and size of the anode end and other details of its design. A number of forms have been made and tried out in this laboratory. The one to be described is undoubtedly not the best possible, but it has fulfilled our requirements sufficiently well to make further studies unnecessary at this time. The tube has two advantages over the usual type: it is much simpler and cheaper to make; at the same time, it seems from our experience to give steadier operation with a more intense useful beam.

A gas tube was adopted only after long experience with hot cathode metal tubes. Where, as in crystal analysis, purity of spectrum is important and a metal tube is to be in daily use, it has been found easier to build a controllable gas tube than to prevent tungsten sputtering in one of the electron type.

A photograph of the tube is shown in Figure 1. Drawings of the essentials of its construction are reproduced in Figures 2-A and 2-B. It is composed of three parts, the anode end, A, with target, a, the cathode C and the glass tube B which serves to connect the two ends while keeping them insulated from one another.

Except for the water jacket, j, and the removable target, a, the anode end is machined from a single piece of solid brass rod. Into this is threaded and soldered the pump connection b. The cap, c, projects into the glass, B, and protects a section of it from sputtering. Flat places, d, are machined on either side of the anode block and holes, e, cut to provide windows for the emitted X-rays. In tubes for structure analysis these windows have been rectangular, as in Figures 2-A and 2-B; for some biological irradiations they have been circular with a diameter of 5/16 inch. They have been covered with 0.001 in. aluminum foil which inspection showed to be free from holes. Care must be taken in mounting these windows to be sure that the cementing wax holds the foil smoothly and tightly. If the smallest bits of wax or dirt get inside the tube, it will be erratic in operation until cleaned. Furthermore, if wax gets unevenly under the windows, they will crack and develop leaks as the tube is successively exhausted and filled with air. Hard de Kotinsky cement or white wax has proved best for these seals. Imperfectly made windows, in our experience, account for a majority of the difficulties with these X-ray tubes. The anticathode, a, is a hollowed-out, water-cooled brass rod threaded into the anode block. The metal to serve as anticathode is either silver soldered or spun into its face, f. It is convenient to have several targets faced with different metals which can be used interchangeably. The seal is effected by filling the cup g with a suitable wax. Black piceïn, as a relatively soft wax which
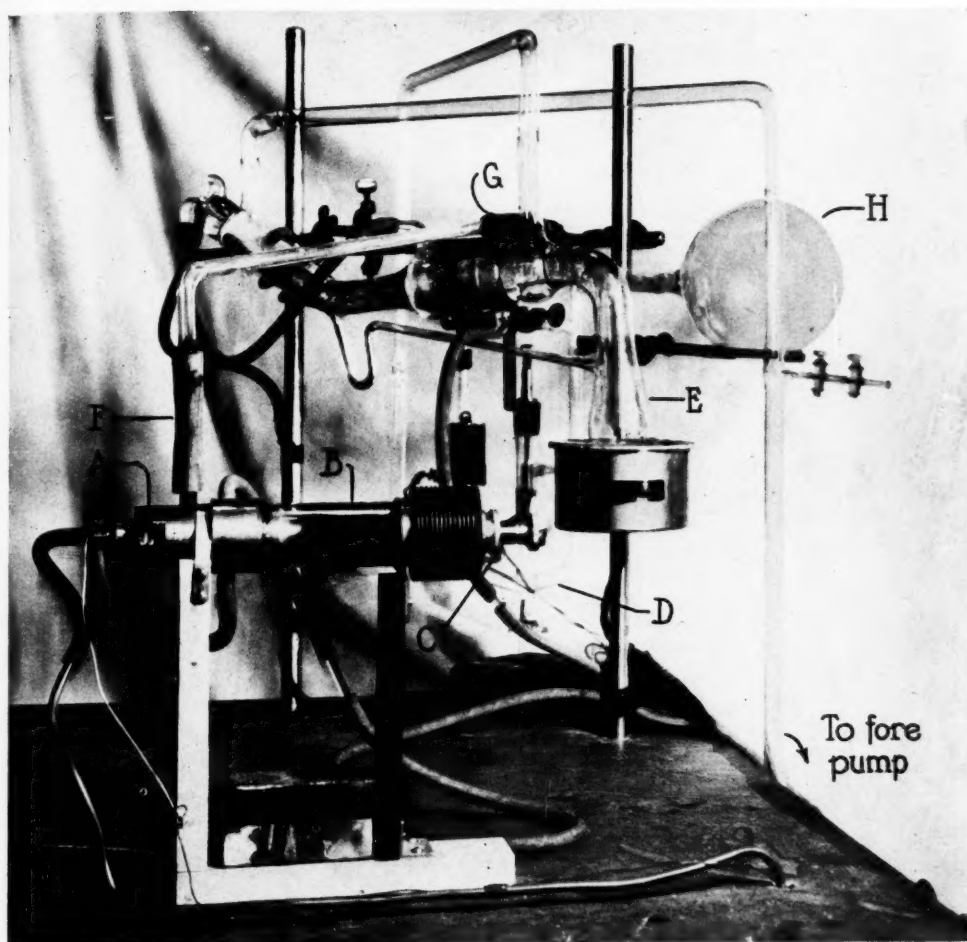
Fig. 1. A photograph of the X-ray tube and its evacuating system. (See Figures 2-*A* and 2-*B*.)

wets brass well, is very satisfactory for this joint. In some early tubes the anticathode was carried on a carefully made and greased vacuum thread. Owing to the difficulty of keeping the interior of the tube free from traces of grease, this construction is not to be recommended.

Except for the cathode piece itself, which is of aluminum, and the radiating copper fins, the cathode is of brass. After long use the aluminum end, which should be slightly concave, may become so pitted as to need refinishing. The size of the focal spot will depend upon the distance between target and cathode (ca. 1.75 in.). In order to be able to adjust this focus without destroying the vacuum in the tube, the cathode is mounted on the vacuum threaded screw h. When well made and lubricated with a good rubber grease, this thread is completely vacuum-tight. The connecting pyrex glass tube, B, is about four inches long for voltages up to 40,000 volts; with higher voltages a six-inch tube has been used. During operation
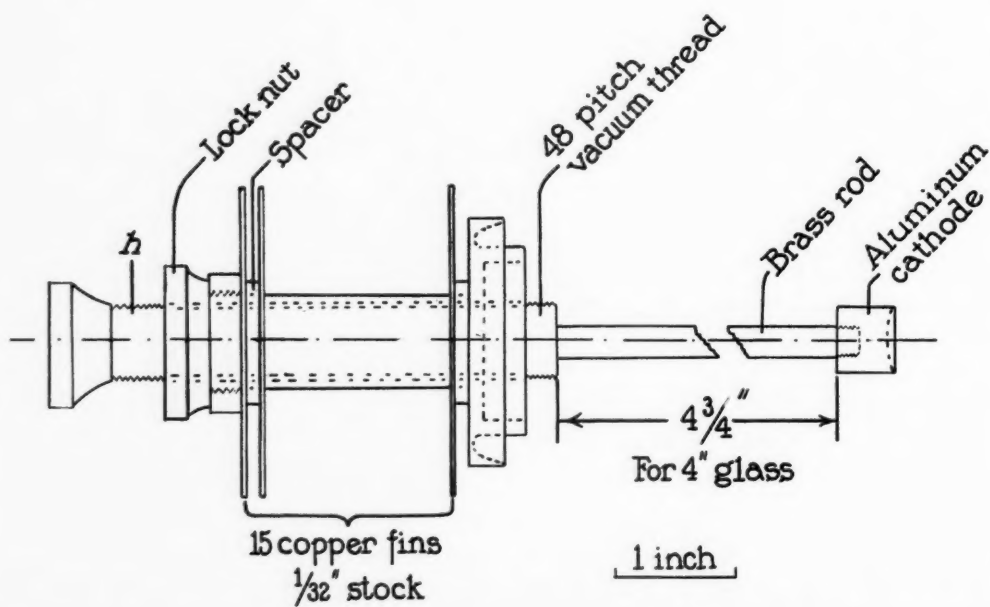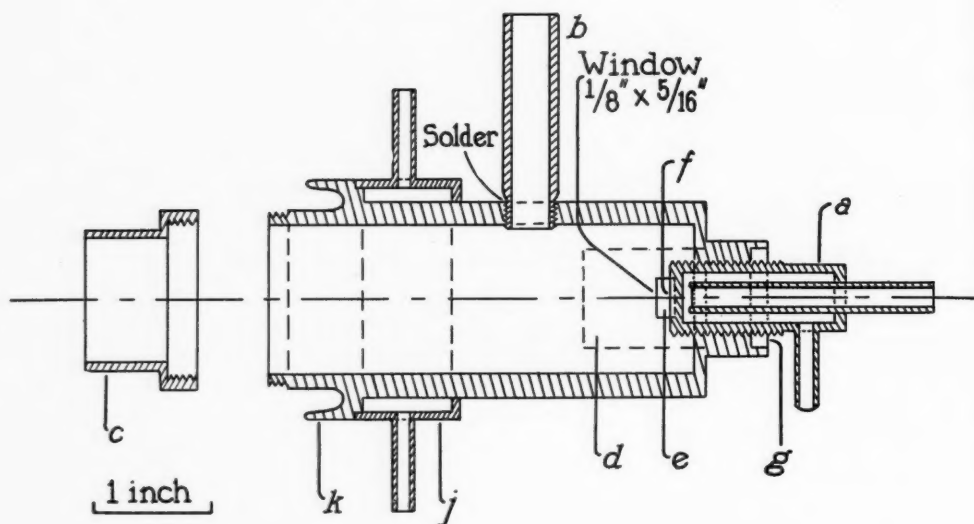
Figs. 2-*A* and 2-*B*. Drawings of the essentials of construction of the X-ray tube. The anode end is shown in 2-*A* (*above*), the cathode in 2-*B* (*below*).

this glass will become warm. On account of the resulting temperature difference between it and the water-cooled metal end at k, a joint made of the best quality red sealing wax is superior to de Kotinsky cement.

In order that apparatus may be brought close to the target, only the cathode is maintained at high potential. Adequate electrical insulation is obtained by making the support m of Figure 1 from hard rubber.

For voltages at least as high as 60 K.V. this tube gives perfect self-rectification with currents of 10 milliamperes. We have not sought to use higher voltages nor have greater current inputs been tried for. In trial runs currents as high as 20 ma. have been used satisfactorily for short periods but for continuous service at such energy consumption the windows should be water-cooled. In routine work we use a current of ca. 5 ma., with a voltage of ca. 40 K.V. This output is set not by the capacity of the tube but by the fact that it gives sufficiently short exposure times and by the belief that the dangers to the experimenter from the stray radiation with stronger beams are not worth the convenience of still quicker photographs. The beam from a copper target obtained under the foregoing conditions will kill in 20 seconds half of the bacteria it strikes at a distance of two inches from the window and would produce corresponding injury to other living cells in its path. It is obvious that unless care is taken the operator may be seriously injured by these rays. With a good and large crystal such as calcite, a satisfactory $30°$ oscillation spectral photograph can be made in from one to two minutes; only rarely do the exposures for small crystals or poorly reflecting faces exceed one hour.

THE VACUUM SYSTEM

For the satisfactory operation of a gas tube the evacuating system is as important as the tube itself. Since the output of X-rays depends on the gas pressure, some device must be used to hold this constant. If a steady output is not desired, one of the several sorts of slow gas or air leaks that were developed for early X-ray tubes could be employed. It is as easy and much more satisfactory to make use of a pressure regulator. Several[1] have been suggested. Each is a valve placed between the tube and the vacuum pump and actuated by a solenoid through which flows current from the primary of the high tension transformer. When the gas pressure in the tube rises, more current is consumed. Acting through the solenoid, this increased current opens the valve and allows the pump to exhaust the tube till the pressure has fallen to its previous level. A drawing of the regulator we use is shown in Figure 3. In the photograph (Fig. 1), it is to be seen at D between the tube and the mercury pump E. The iron core, n, floats on the surface of mercury. When lifted by the solenoid the mercury level in p drops and connection is established between q and r through slots,[2] w. The tube current regulated in this way is approximately adjusted by raising and lowering the iron cap, s, using the vacuum threaded screw, t. Accurate setting is effected by altering the current through the solenoid, which is connected in parallel with a variable resistance in the primary circuit of the transformer. The pull on the core may be varied by changing the height of the solenoid. When trial has shown the most sensitive position, it can be held in place with a ring of insulating tape wound around the glass tube. The characteristics of a suitable electrical circuit are shown in Figure 4.

The stopcock u is left open while the system is pumping to about the desired pres-

[1] R. M. Bozorth, Jour. Am. Chem. Soc., 1927, XLIX, 971; F. E. Haworth, Jour. Opt. Soc. Am., 1929, XIX, 79; T. N. White, Jour. Sci. Inst.

[2] T. N. White, *op. cit.*

To x-ray
tube

To diffusion
pump

#18
wire

t

g

s

n

r

w

v

p

u

1 inch
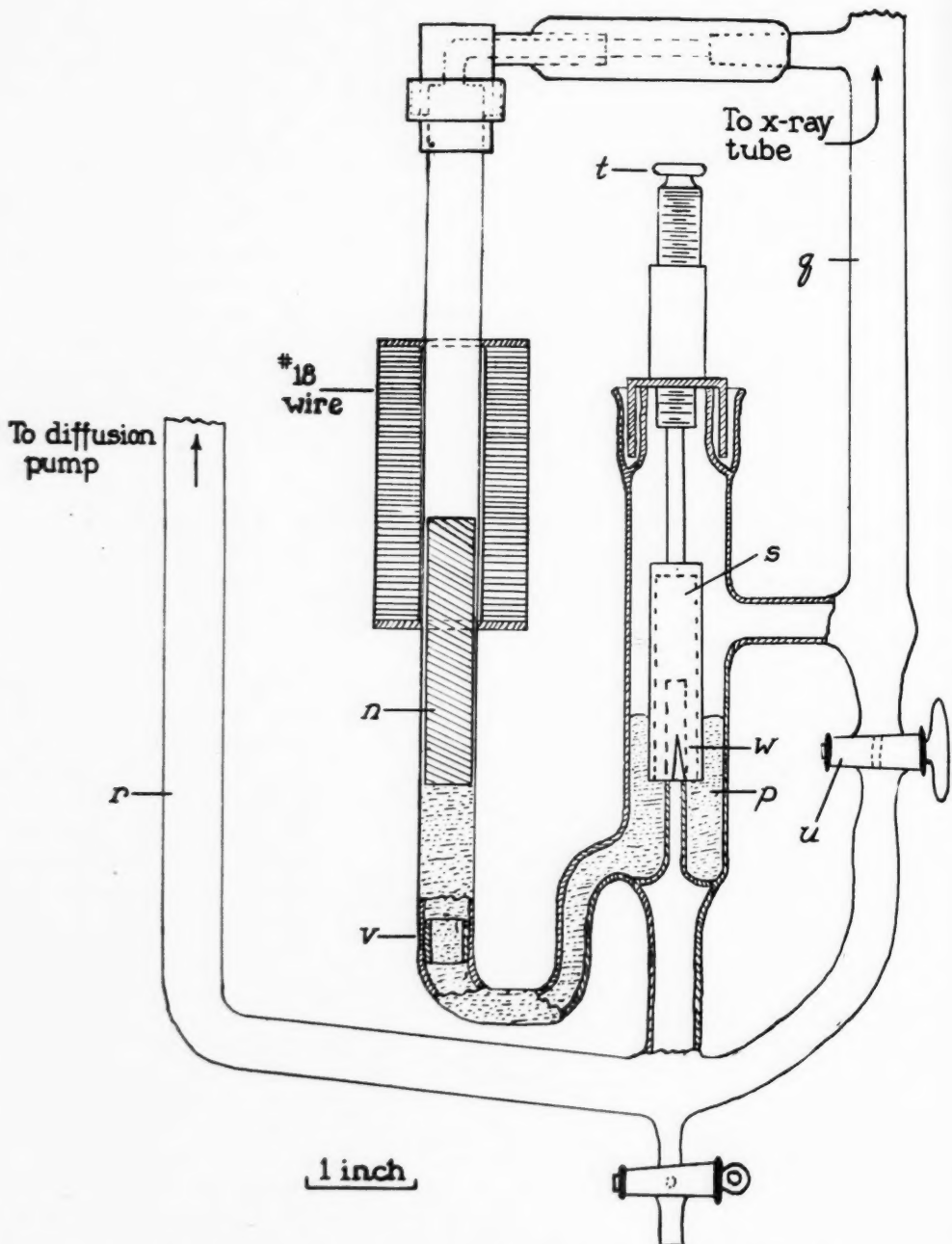
Fig. 3. A drawing showing details of the gas pressure regulator D of Figure 1.

sure; during operation it is closed. If small particles of grease or dirt accidentally get into the X-ray tube, the consequent large and erratic evolution of gas may cause the iron core to jump violently. To prevent

not require more than half an hour. We follow the same general routine of complete evacuation and slow raising of voltage every time the tube is to be used. As long, however, as the output is not to be changed, the
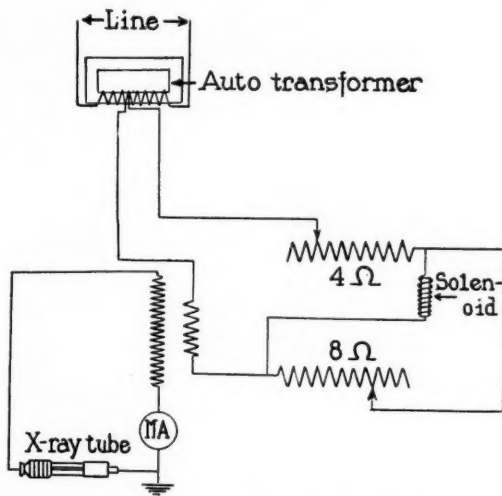
Fig. 4. An electrical circuit suitable for the operation and control of the X-ray tube.

breakage of the containing arm, a carefully cleaned piece of rubber tubing is shellacked into place at v to serve as a bumper.

In breaking in a new tube, it is best to evacuate it till it is completely hard and then to raise the voltage by steps till no current is passed, even momentarily, at the highest potential to be used. For 60 K.V. this should not take more than ten or fifteen minutes if the tube is clean inside and its seals properly made. The voltage should then be reduced to a low value, the stopcock u closed and the screw t manipulated to allow the tube gradually to soften. As soon as it begins to pass rectified current, as indicated by the milliammeter, the voltage should be raised slowly to the desired value. Frequent use of the stopcock probably will be needed to control the gas pressure until adjustment has been made for the current and voltage to be used. If the tube and system are tight, the whole procedure should

screw, t, need not be adjusted and ordinarily the tube is ready for use within ten minutes of the time the pumps are started.

For steadiest operation it is better not to have the system absolutely tight. Satisfactory results have been obtained by introducing a pair of rubber junctions of nitrometer tubing at F and G of Figure 1. The glass-rubber and metal-rubber surfaces are shellacked but the rubber itself is not painted. The consequent flexibility makes connection of the tube easy and the rubber seems sufficiently porous to give a suitable leakage of air. If the mercury pump is fast, it is perhaps better to increase the volume by introducing a flask such as H.

Where a very steady output is desired, a controllable air leak may be added and a mercury trap cooled in alcohol and solid CO_2 interposed between diffusion pump and tube. With this arrangement a tube will operate day after day for hours at a time

with a maximum current fluctuation of ca. 0.1 ma., provided occasional adjustment is made of the solenoid rheostat to take care of gradual hardening after evacuation. When equal voltages are maintained across a tube and equal currents through it, ionization measurements with an air chamber made on successive days have been found constant within the accuracy of the method (ca. 2–3 per cent).

ANALYSIS OF DIAPHRAGM SYSTEM FOR THE X-RAY STANDARD IONIZATION CHAMBER[1]

By LAURISTON S. TAYLOR, Bureau of Standards, WASHINGTON, D. C.

IN measuring the ionization in an *unrestricted volume of atmospheric air,* according to the internationally adopted definition of the r-unit,[2] the accuracy of the determination depends principally on, first, the electrical measurements of the ionization and control of the X-ray output; secondly, the determination of the air volume of which the ionization is being measured. The first has been treated by Behnken,[3] Glasser,[4] Duane,[5] and more recently by the author;[6] the second is effectively the object of the present paper.

Behnken,[7] in a comparison of the r-unit between the laboratories of Glasser, Duane, Grebe, Küstner, Holthusen, and the Physikalisch-Technische Reichsanstalt, found a 4 per cent discrepancy among the different laboratories. In his publication of the results of this comparison no explanation is offered for the disagreement, it being assumed to be due to faulty experimental technic rather than to the theory of the experiment. In a study by the author[8] of the various measuring methods, a source of error sufficient to account for Behnken's results was traced to the measurement of the ionization current. However, it is recognized that even an agreement between two laboratories might arise from the errors present compensating each other, so that it is very desirable to study the possible errors in the various other controlling factors.

In practice, the ionization is measured in several cubic centimeters and the ionization current divided by the corresponding air volume, the ionization throughout the entire volume being assumed to be uniform. However, this is not, in general, the case, and so we must determine the effective volume corresponding to uniform ionization. In some recent work Failla[9] has measured air ionization in a standard chamber, using widely varying diaphragms, and found that, according to the particular diaphragm system used, there may be a considerable uncertainty in the determination of the air volume.

Behnken, Glasser, and Failla have used circular diaphragms of the order of 1 cm. diameter, while Duane uses a rectangular slit system where his chamber diaphragm is 0.5 by 5.0 centimeters. Most of the observers have placed a screening diaphragm close to the tube to prevent radiation from the target stem entering the standard chamber. Depending upon its relative size and position with respect to the focal spot, this diaphragm may or may not have a direct bearing on the ionization readings.

It, therefore, seemed advisable to analyze the effects of the diaphragm system carefully so as to obtain some quantitative measure of the error introduced by certain assumptions regarding it. We shall, therefore, treat the problem, first considering the focus as a point source (Sec. II, 1), then as an extended source (Sec. II, 2), and finally show

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[2]The r-unit is defined as "the quantity of radiation which, when the secondary electrons are fully utilized and the wall effect of the chamber is avoided, produces in 1 cubic centimeter of atmospheric air at 0° C. and 76 cm. mercury pressure such a degree of conductivity that one electrostatic unit of charge is measured at saturation current."

[3]Behnken, Hermann, and Jaeger, Robert: Ztschr. f. tech. Phys., 1926, VII, 564.

[4]Glasser, O., and Portmann, U. V.: Am. Jour. Roentgenol. and Rad. Ther., January, 1928, XIX, 47.

[5]Duane, William, and Lorenz, Egon: Am. Jour. Roentgenol. and Rad. Ther., May, 1928, XIX, 461.

[6]Taylor, L. S.: Bureau of Standards Journal of Research, 1929, II, 771.

[7]Behnken, Hermann: Strahlentherapie, 1928, XXIX, 192.

[8]See Footnote 6.

[9]Failla, G.: Am. Jour. Roentgenol. and Rad. Ther., January, 1929, XXI, 47.
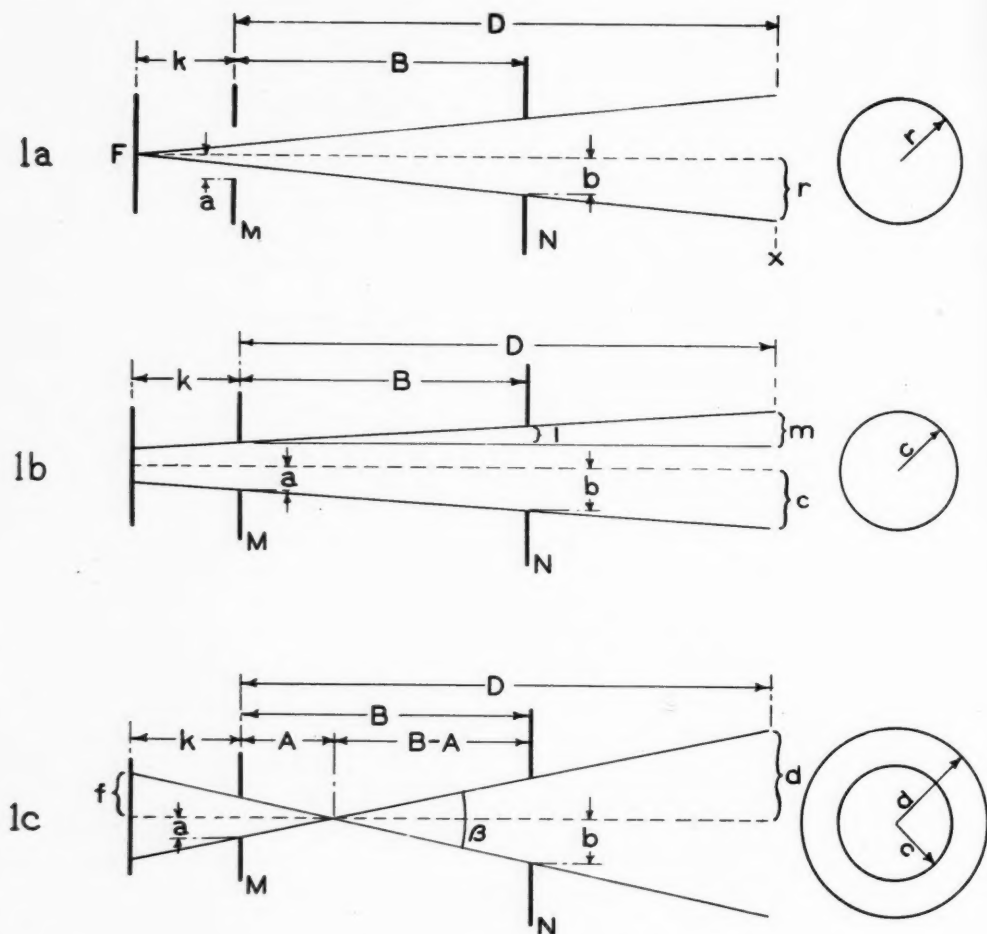
Fig. 1. Diaphragm system.

the experimental justification (or failure) for the assumption made (Sec. III, 2).

II. GEOMETRICAL ANALYSIS OF THE DIAPHRAGM SYSTEM

1. *Behnken's analysis, assuming a point source of radiation.*—In this it is assumed that the focus is a point source of radiation, and that the X-ray flux density is uniform over the cross-sectional area of the beam in the ionization chamber. When the diaphragms are very small compared with their separation, these two assumptions may be considered valid; but, in general, they are contradictory, since the radiation from a point source gives a flux density in the direction of the beam which is proportional to the cosine of the angle that the given ray makes with this axis.

In presenting Behnken's analysis,[10] we shall use for ease in the later development a nomenclature differing slightly from his. Referring to Figure 1(a), F is the focus of the X-ray tube, M the first diaphragm, radius a; N the ionization chamber dia-

10Behnken, Hermann: Strahlentherapie, 1927, XXVI, 79.

phragm, radius b, and x a plane in the ionization chamber normal to the axis of the beam.

The focus is assumed to be a point, the X-ray intensity of which is represented by a flux density of I_o at unit distance. Then on the axis of the beam at x, the intensity, or flux per unit area, is given by

$$I_x = \frac{I_o}{(D+k)^2} \qquad (1)$$

provided, of course, that the radiation be sufficiently penetrating to permit loss by absorption in the length $(D+k)$ to be neglected. Letting r equal the radius of the cross-section of the beam at x, we see that

$$\frac{r}{b} = \frac{D+k}{B+k}$$

so that the cross-sectional area of the beam at x is

$$\pi r^2 = \frac{\pi (D+k)^2 b^2}{(B+k)^2} \qquad (2)$$

The volume of an element of length dx of the beam is $dV = \pi r^2 dx$. The energy dE absorbed therein per unit time is

$$dE = \varkappa I_x dV \qquad (3)$$

where $\varkappa$ is a constant. The number of ions produced by this absorbed radiation being proportional to dE, the electrical measurement of the ionization gives a quantity proportional to the X-ray intensity I_x.

From the equations (1), (2), and (3) above we find that the energy absorbed in the element at x is

$$dE_1 = \frac{\varkappa I_o}{(D+k)^2} \cdot \frac{\pi (D+k)^2}{(B+k)^2} b^2 dx \qquad (4a)$$

$$= \varkappa \frac{\pi b^2}{(B+k)^2} I_o dx \qquad (4b)$$

Equation (4b) expresses, however, the energy absorbed in a volume of cross-sectional area πb^2 and thickness dx, located at

a distance $(B+k)$ from the point source (that is, at the diaphragm N). Therefore, for any length L_o of the chamber, the total energy E_1 absorbed in the chamber is given by

$$E_1 = \frac{\varkappa \pi b^2}{(B+k)^2} I_o L_o \qquad (4c)$$

As a consequence we are justified in considering the effective air volume as having a radius b, a length equal to the effective length of the measuring electrode, and located at a distance $(B+k)$ from the focus. The question as to what part of the ionized air volume the distance must be measured, in applying the inverse square law, is thus answered. In a previous paper the author has given the necessary electrical conditions to determine accurately this effective length L_o of the air column from which the ionization is being measured.

2. *Analysis assuming an extended source of radiation: (a) general treatment.*—Mayneord[11] and others have considered the focus as an extended source, but exaggerated, as shown below, the importance of the error introduced by assuming a point source. To estimate this error another assumption will be made which, while not quite correct, is indicated by experimental evidence to be a closer approach to the true conditions.

Consider the focus to be an extended source having an area at least as great as the projected area of the diaphragm N upon the target. (Fig. 1 (c).) Let, further, the "brightness" (in the optical sense) of the focal spot be uniform both as to area and direction viewed. Then over the plane x the distribution of flux density varies in a manner determined by the diaphragm system. There will be a *central area* of radius c (Fig. 1(b)), having a nearly uniform distribution, and a surrounding *ring area* of outer radius d (Fig. 1 (c)), having a non-

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11 Mayneord, W. V.: Brit. Jour. Radiol., 1928, N. S. I, 125.

uniform distribution. Their dimensions are readily obtained.

To find the radius c of the central area, consider the system of Figure 1(b)

$$\frac{b-a}{c-a}=\frac{B}{D}$$

from which

$$c=\frac{Db-Da+Ba}{B} \qquad (5)$$

For the outer radius d of the penumbra, Figure 1(c) gives.

$$\frac{a}{b}=\frac{A}{B-A} \text{ or } A=\frac{Ba}{a+b}$$

also

$$\frac{B-A}{b}=\frac{D-A}{d}$$

whence

$$d=\frac{D-A}{B-A}b$$

substituting the value of A above

$$d=\frac{Da+Db-Ba}{B} \qquad (6)$$

It is seen that the values of c and d are independent of the distance k from the focus to the first diaphragm M, and, as experimentally demonstrated in Section III, 2, we are thus justified in considering the first diaphragm M, as the source of radiation, whose brightness is also, like that of the target, uniform with both direction and area for the small angles under consideration.

If now, the *aperture* of the system be defined as the solid angle β (Fig. 1 (c)) between the most divergent rays passing through the two diaphragms, we see that the first diaphragm may be considered as the source of radiation only if the actual area of the focal spot fills the aperture β of the system. This limiting condition is seen from Figure 1(c), where f is the radius

of the focal spot. Its magnitude is taken from

$$\frac{f}{a}=\frac{A+k}{A}$$

from which

$$f=\frac{ka+kb+Ba}{B} \qquad (7)$$

by substituting the value for A as derived in Equation (6).

To determine the flux density at any point on the plane x due to the total emission from the focus, we may use the cosine law of emission and illumination as expressed by

$$dI_x=\frac{I_o\cos^2\alpha \, da \, dc}{D_{ac}} \qquad (8a)$$

where I_o is the flux density at the target in the direction along the axis of the beam and likewise also the corresponding flux density through the area at M; dI_x is the flux density through an element of area dc in the plane x, and in a direction normal thereto; α the angle which the line joining da and dc makes with the normal to these areas, and D_{ac} the distance between the elements. The total flux I_x at any point on the plane is obtained by integrating the flux received from the various elements of the surface πa^2 of the diaphragm M. This has been evaluated by Foote[12] for the illumination from a radiating disk.

If β_0 is the angle between the axis and the most divergent ray, then referring to Figure 1 (c), for $\cos^2 \beta_0=0.9950$, $\cos \beta_0$ can be assumed equal to unity without introducing an error greater than 0.5 per cent in the flux density at any point. This condition is true for the experimental arrangement of most observers. With a system

12Foote, P. D.: Bureau of Standards Bulletin No. 263, 1916, XII, 583.

such as used by Duane, however, it is not negligible.[13]

In the case where $\cos^2 \beta_0 = 0.9950$, we may assume the flux density I_x uniform over the central area (Fig. 1 (b)) and given by

$$I_x = \frac{I_o}{D^2} \qquad (8b)$$

where, since D is the distance from the plane x to the first diaphragm M, the effect at x is as if the source were located at the diaphragm M.

The energy dE_2 absorbed in the central volume element dv of cross-sectional radius c and thickness dx is then

$$dE_2 = \varkappa I_x dv$$

$$= \varkappa \frac{I_o}{D^2} \pi c^2 dx$$

$$= \frac{\varkappa \pi (Db - Da + Ba)^2}{B^2} \cdot \frac{I_o}{D^2} dx \quad (9a)$$

Like dE_1 in Equation (4a), dE_2 is proportional to the ionization current measured. In the special case where the two diaphragms are equal $a = b$ and thus

$$dE'_2 = \frac{\varkappa \pi b^2}{D^2} I_o dx \qquad (9b)$$

It will be noticed that dE'_2 in Equation (9b) has the same form as dE_1 in Equation (4b), the only difference lying in the replacement of $(D+k)$ by D. It remains to determine the ionization in the penumbra, which may be neglected when using very small diaphragms very far apart, but not in general.

The ionization produced in a volume element of the surrounding ring area or penumbra of outer radius d can not be easily calculated, owing to the fact that from any

given point on the ring only a fraction of the first diaphragm is visible. Thus, at the inner radius of the ring the X-ray flux density is equal to that of the inner area while at the outer edge it is zero.

(b) Effective volume of air ionized.— Having found the effect in the central area as above, one might proceed by using Foote's derivation to evaluate that in the penumbra, but a simpler and more direct method is suggested by the derivation above for the effect of a point source.

We proceed, therefore, to determine the total energy absorption within the chamber, regardless of its distribution. Since it is permissible to neglect the loss in flux arising from absorption along the path, it is obvious that the ionization in a length dx in any cross-section of the beam at any plane x within the ionization chamber is proportional to the total flux through that cross-section. This is given, however, by the total flux entering the diaphragm N. The combined result along any length L of the beam in the ionization chamber is equal then to that of a beam having a cross-section equal to that of the entrant diaphragm N and a total flux density equal to that at N. This gives for each element of length

$$dE_3 = \frac{\varkappa \pi b^2 I_o}{B^2} dx \qquad (10)^{14}$$

Summing up for the whole effective length L_0 of the measuring electrode, we have

$$E_3 = \frac{\varkappa \pi b^2 I_o}{B^2} L_0 \qquad (11)$$

Equation (11) has the same form as that of Behnken, Equation (4c), the difference being in the location of the effective source of the X-radiation at the diaphragm instead of the focus.

We have thus established that for either

[13] It must be pointed out that the cosine law cannot be applied rigorously to X-radiation. However, by considering the energy distribution about an X-ray tube target, we see that over small ranges the error introduced by assuming this law is very small. If we consider the change in flux density over a plane, from a point or extended source, as due simply to the change in distance from the source, we arrive at an equation identical with Equation (8a).

[14] Equation (10) may also be obtained from Equation (9a) by the process of decreasing D until it is equal to B, at which point the penumbra disappears, with consequent simplification of the problem.
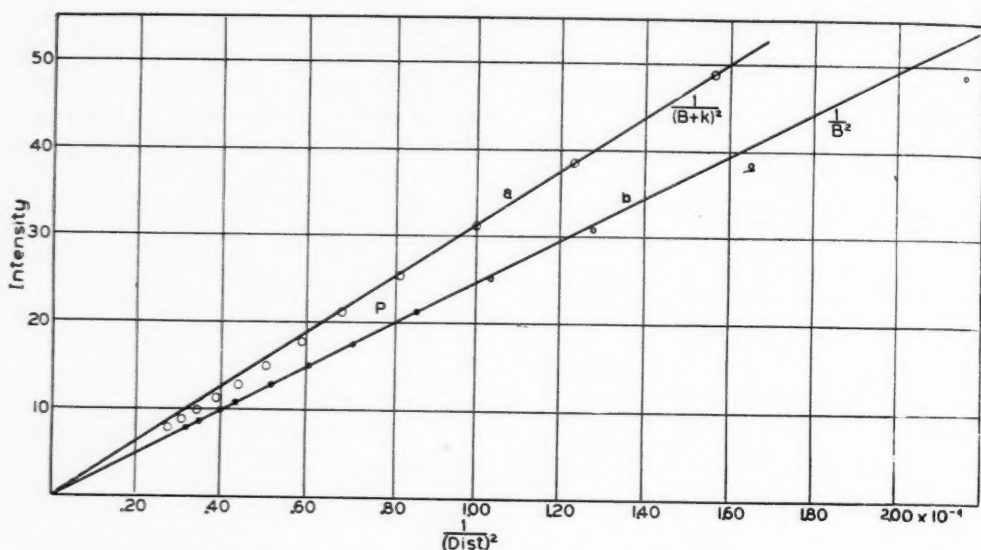
Fig. 2.   Intensity of measured ionization as a function of $1/(\text{distance})^2$.

a point source (Equation (4b)), or an extended source within fixed limits (Equation (10)) the product of the area of the ionization chamber diaphragm by L determines the *effective air volume;* with the condition that in the first case the inverse square law is used with the source at the focus, while for the second it is used with the source considered at the first diaphragm M. The experimental justification for this is given in Section III.

Equation (11) should express actual conditions within experimental limits so long as $\cos^2 \beta_0$ differs from unity by less than the permissible experimental error. Having fixed the maximum permissible variation in flux density we may determine the range of magnitudes over which the equations above are valid. This, of course, depends upon the aperture of the system, so that for any given system the region over which an accurate determination of the r-unit is possible may be determined.

As indicated in Figure 1 (c), the focal spot must fill the aperture if the assumptions

made are valid; that is, from Equation (7) we must have

$$f > \frac{ka + kb + Ba}{B} \qquad (12a)$$

If in a particular case

$$f < \frac{ka + kb + Ba}{B} \qquad (12b)$$

for a part of the range of B, then the inverse square law should be applied, using the distance from diaphragm N to the focus instead of to M, the diaphragm M serving simply to reduce the radiation coming from points other than the focus. If we have a sufficiently small focal spot (one which never fills the aperture) and a diaphragm system such that $\cos^2 \beta_0 \geqq 0.995$, we can determine the volume of ionized air as accurately as the experimental precision warrants by assuming a point focus. These conditions have not been realized by all observers.

III. EXPERIMENTAL STUDY OF DIAPHRAGM SYSTEM

1. Type of diaphragms used.—First, a study was made to determine if the form

(12a)) by the extended focal area the distance B between diaphragms M and N should be used and the inverse square law applied thereto. When it is not filled, the distance $(B+k)$ from the focus should be used.
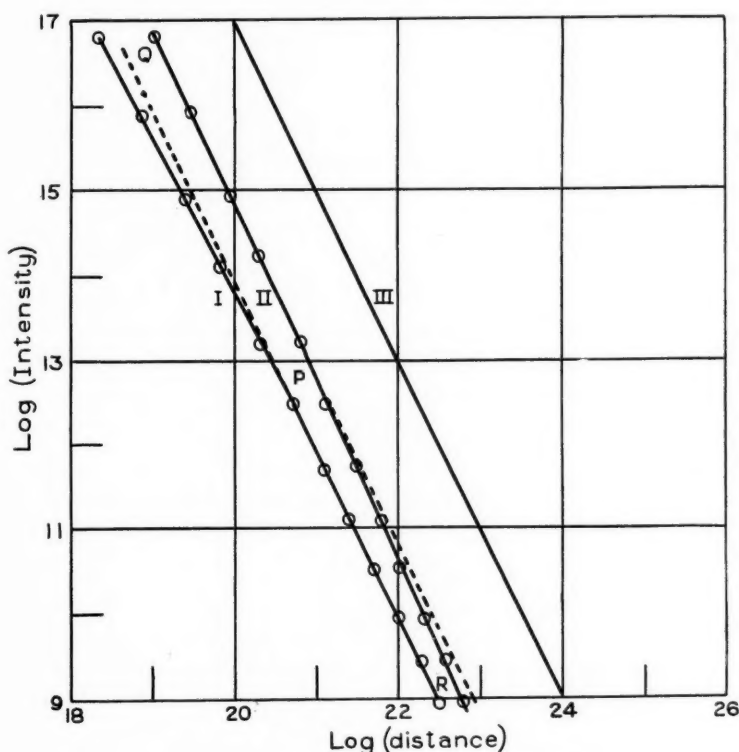
Fig. 3. Validity of inverse square law.

of the edge of the circular diaphragms used affected the measured magnitudes. One-quarter inch lead diaphragms having the same diameter (10 mm.) were prepared, all having different edges. The first group were tapered, ranging from 0° to 15°. The next group were beveled, leaving a half thickness of lead as an edge. In no case was a measurable difference produced in the ionization current. The diaphragms subsequently used were all of this beveled type.

2. Test of inverse square law.—According to Section II, 2, so long as the aperture of the diaphragm system is filled (Equation

To test this the ionization chamber was mounted on a track of such length that the distance between focus and limiting diaphragm N could be varied from 40 to 200 cm.; the radius of the diaphragm M could be varied from 2 to 6 mm. and that of N from 2 to 10 millimeters. A null reading electrostatic system was used for measuring the ionization currents and a constant voltage generator for the X-ray tube.[15]

To align the system accurately, the ionization chamber track was leveled and approximately adjusted by sighting through the dia-

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[15] See Footnote 6.

phragms at the target. A fine wire was then strung along the axis of the system and the track further adjusted until the wire remained in the center of the front and back chamber diaphragms for all positions of the

0.61, obtained when the break occurred at $B=105$ centimeters.

Likewise if i is plotted against $1/(B+k)^2$ a break occurs at the point corresponding to $B=110$ cm. (Curve a) except that in this
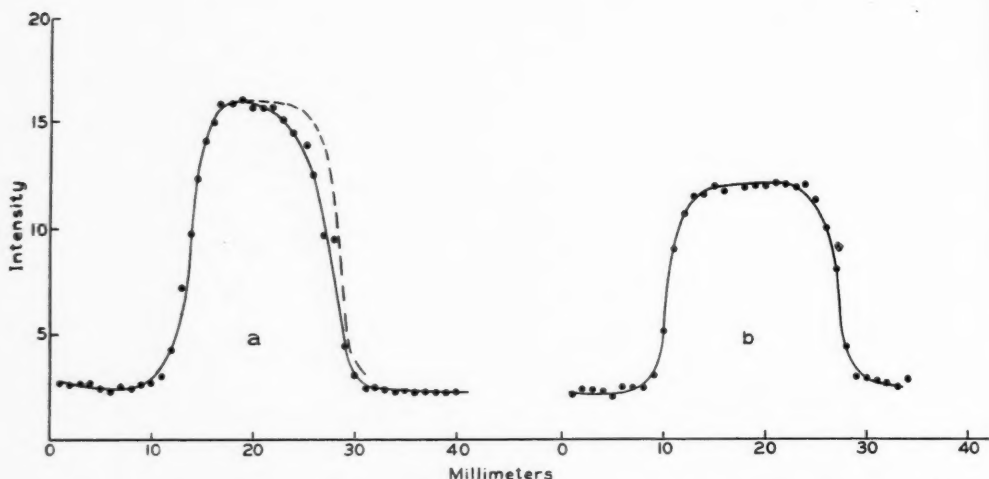
Fig. 4. Distribution of intensity across the standard X-ray beam. (The relative height of Curves a and b has no significance.) Curve a, for displaced diaphragms; Curve b, for properly aligned diaphragms.

chamber along the track. This was accomplished even more accurately by inserting in the diaphragms disks having very small holes in the center.

Curve b in Figure 2 gives (for $a=b=0.5$ cm., $k=12$ cm., and $f=$about 0.62 cm.) the observed X-ray intensity or ionization current i, plotted against the inverse square of the distance B between the tube focus and the ionization chamber diaphragm N. As should be expected, up to a certain value of $1/B^2$ corresponding to a distance $B=105$ cm., the intensity is found to be strictly proportional to $1/B^2$. According to Equation (7), a break in this proportionality should occur when

$$\frac{ka+kb+Ba}{B}=0.62$$

Thus in this case the calculated value of f is 0.62 as compared with the observed value

case the portion of the curve corresponding to distances near the tube obeys the inverse square law.

The inverse square law may be expressed as

$$\log i=\log c-2\log H \qquad (13)$$

where c is a constant and H is the distance, either B or $(B+k)$ as the case may be. By plotting (Fig. 3) the data, the log of the intensity (proportional to $\log i$) against that of the distances B or $(B+k)$, as the case may be, the applicability of Equation (13) is tested. For Curve I, H is taken as the distance B between diaphragms M and N; while in Curve II, H is taken as the distance $(B+k)$ between N and the focus. Curve III represents the slope (minus 2) which Curves I and II should have if the law expressed in Equation (13) is obeyed. It is to be seen that, of Curve I, the portion PR is parallel to III; while of Curve II, the por-

tion PQ is parallel to *III*. Hence the experimental results bear out the conclusions that for distances within a certain range near the tube the inverse square law should be applied with the distance $(B+k)$; while

photometer, is plotted against position across the beam. With the X-ray tube and first diaphragm displaced laterally about 0.5 cm. from the central position, a photographic plate exposed inside the ionization chamber,
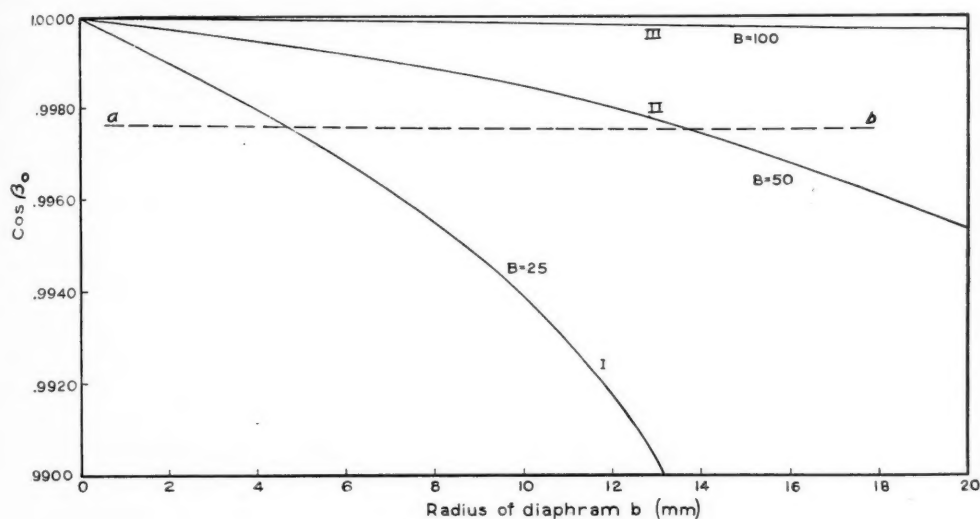
Fig. 5. See text, this page.

over the range farther from the tube, the distance B is used instead.

It is thus clear that the assumption of neither a point source nor an extended source is valid under all conditions; hence, special care must be taken in any experimental set-up to decide which may be used.

3. *Uniformity of X-ray flux.*—To check if the flux obeyed the conditions assumed for deriving the equations of Section II, the uniformity of the flux over the cross-section of the beam in the center of the ionization chamber was tested by exposing photographic plates in this plane, the exposure being varied over wide limits of time. With a proper alignment of the diaphragm system, the distribution over the central area should be uniform. That this proved true is shown in Figure 4 (b) where the photographic density, obtained by measuring the resulting photographic plate with a Marten's

gave the distribution shown in Figure 4 (a)—the dotted line giving the expected density for a perfectly symmetrical beam. As expected, the densities were greater on the side toward which the source was shifted. The irregularity with which the observed curve fluctuates about the smooth curve can well be ascribed to the inhomogeneity of the photographic emulsion.

4. *Choice of operating conditions.*— Two special cases may be given which illustrate how the geometrical analysis of the diaphragm system permits conditions to be chosen that yield an accurate determination of the ionization per unit volume. Letting β_0 be the maximum angle of divergence between the axis and the rays passing through the diaphragm system, then Curves I, II, and III (Fig. 5) give the values of cos β_0 plotted against the radial position in the ionization chamber for three cases where
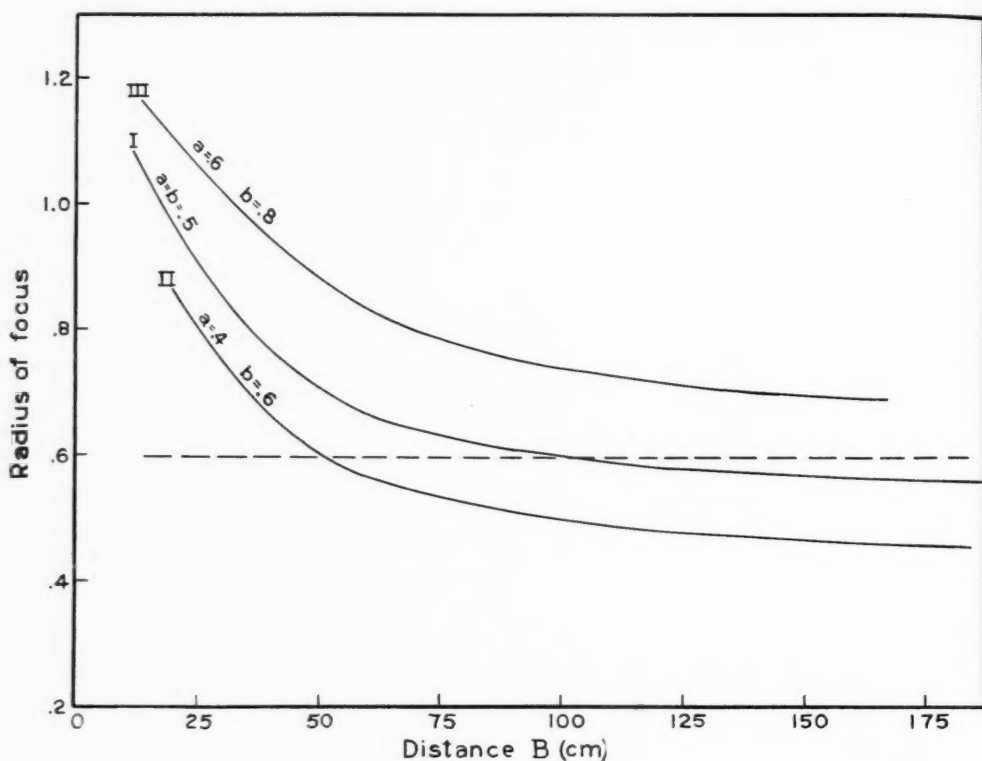
Fig. 6.   See text, this page.

B=25, 50, and 100 cm., respectively, where a=0.4 centimeter. The values of cos β_0 are obtained from the relation

$$\frac{\beta_0}{2} = \tan^{-1} \frac{a+b}{B}$$

from Figure 1 (c).

If we stipulate that $\cos^2 \beta_0$=0.9950 introduces the maximum permissible error—which means an error of less than 0.25 per cent in r-units—it is seen that any physical conditions whereby cos β_0=0.9975 may be used. Thus the intersection of any curve in Figure 5 with the line ab=0.9975, gives at once the upper limit within which our approximations would be valid. In Curve I for B=25 cm. it is seen that b must not exceed about 0.5 cm.; in Curve II for B=50 cm., b must not exceed 1.4 cm.; while Curve

III for B=100 cm. indicates that b may become extremely large before exceeding the given limit.

From Equation (7), giving the radius of the focal spot necessary to fill the aperture, we may plot curves which indicate the diaphragms and distances which may be used and yet fulfill the condition that $f > (ka + kb + aB)/B$. If, for instance, we have a focal spot of radius 0.6 cm., any set of conditions composing the portion of the curve (Fig. 6) below f=0.6 may be used. Thus in Case I, where the diaphragms M and N have a radius of 0.5 cm. each, the distance B must never be less than 100 centimeters. In Case II where a=0.4 and b=0.6 cm., B may be reduced to 50 cm., while for a=0.6 and b=0.8 cm. no value of B whatever will suffice.
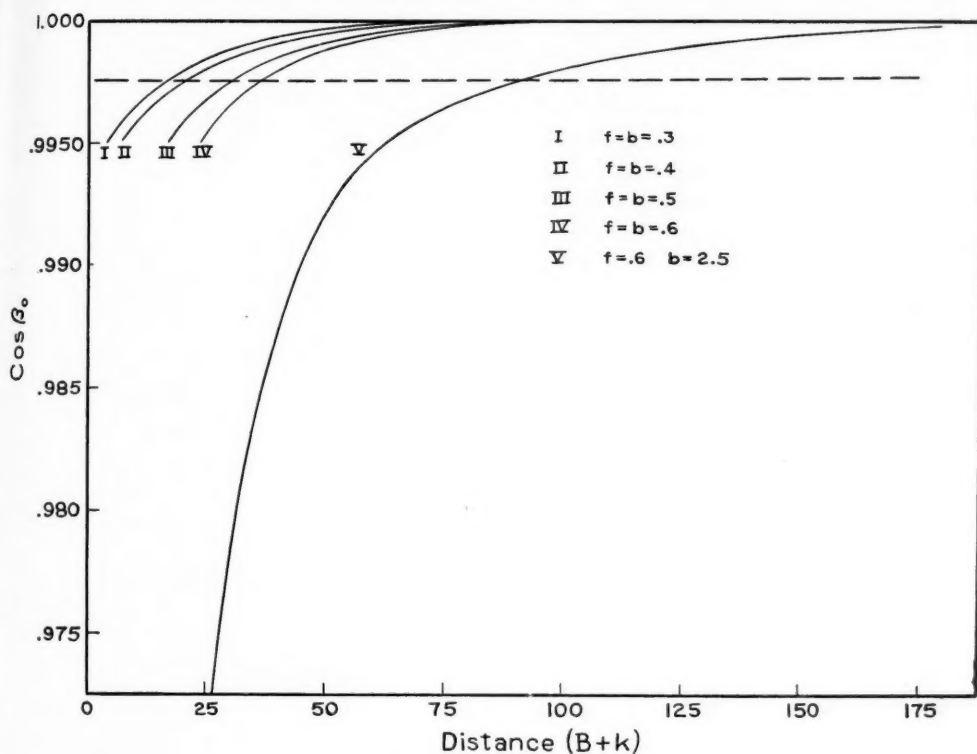
Fig. 7. See text, this page.

In the standardization equipments used by Behnken, Duane, and Glasser, each has a diaphragm corresponding to M. However, it is probable that their focal spots did not completely fill the aperture of the system, so that for the purpose of indicating the allowable deviation in each, we may consider the aperture as determined by the radii of the focal spot and diaphragm N and the distance $(B+k)$. We may then compute $\cos \beta_0$ as a function of $(B+k)$ for different radii of the diaphragm N and so determine the range over which the allowable error in measuring the air volume is not exceeded. A set of these relations are plotted in Figure 7. All conditions falling on the curves above the line at $\cos \beta_0 = 0.9975$ may then be used without introducing more than the stipulated error.

Consider now three of the well-known X-ray standardization equipments:

I. Behnken[16] (Physikalische Technischen-Reichsanstalt).—$(B+k) = 105$ cm.; the radius of the focal spot f and diaphragm N are about the same and equal to 0.35 cm., making $\cos \beta_0$ fall between Curves I and II in Figure 7, thus indicating a very small error which may be neglected.

II. Glasser[17] (Cleveland Clinic).—$(B+k) = 45$ cm. and $f = b = 0.4$ centimeter. The point fulfilling these conditions falls on Curve II, well above $\cos \beta_0 = 0.9975$, also indicating a very small error.

In the two cases above, the focal spot may be slightly greater than indicated, but,

16Behnken, Hermann: Strahlentherapie, 1927, XXVI, 79.
17See Footnote 4.
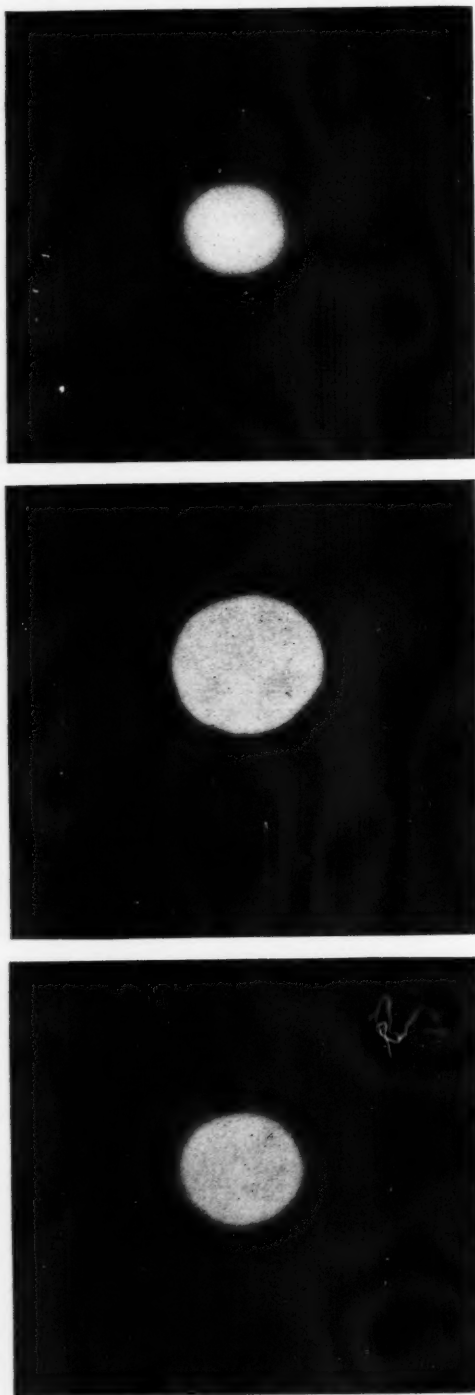
Fig. 8.   Pinhole photographs to indicate the magnitude of off-focus radiation.

even so, the maximum error will be less than 0.5 per cent.

III. Duane[18] (Harvard University).— This system has for N a rectangular diaphragm 0.5 by 5.0 cm., and $(B+k)$ is approximately 60 centimeters. The energy distribution across the beam in the 0.5 cm. direction will be uniform within the necessary limits. Along 5.0 cm. direction, however, the variation in cos β_0 with $(B+k)$ is shown in Curve V, whence it is seen that for $(B+k)=60$, the maximum error in cos^2 β_0 is about 1.6 per cent, and, therefore, can not be neglected. In order to reduce this error to within the prescribed limits, we must make $(B+k)=90$ centimeters.

IV.   INFLUENCE OF "OFF-FOCUS" RADIATION

Off-focus radiation may be defined as that *radiation from an X-ray tube which originates from points on the target face other than the sharply defined focal spot.* If a diaphragm M be used which is sufficiently small, "off-focus radiation" does not enter. In this radiation lies another possible source of error in standardization measurements, and on account of the difficulty in accurately measuring its magnitude most observers have avoided a quantitative study of the question. Glasser[19] has indicated the importance of screening the ionization chamber diaphragm (N) from radiation coming from the stem and the body of the target other than the face. Likewise, Behnken,[20] Failla,[21] Duane[22] and most others have taken similar precautions, although in every case the method was entirely arbitrary.

A pinhole photograph of the target taken through the diaphragm system will indicate any source of off-focus radiation. Especial

18 See Footnote 5.
19 See Footnote 4.
20 See Footnote 16.
21 See Footnote 9.
22 See Footnote 5.

care, however, must be used in making such photographs, since an under-exposed plate may apparently indicate a good focal spot and little off-focus radiation; an over-exposure indicates general radiation from the

at times be of too great a magnitude to be neglected.

To measure the off-focus radiation, the diaphragm N was fixed and the ionization chamber placed at a fixed distance from the
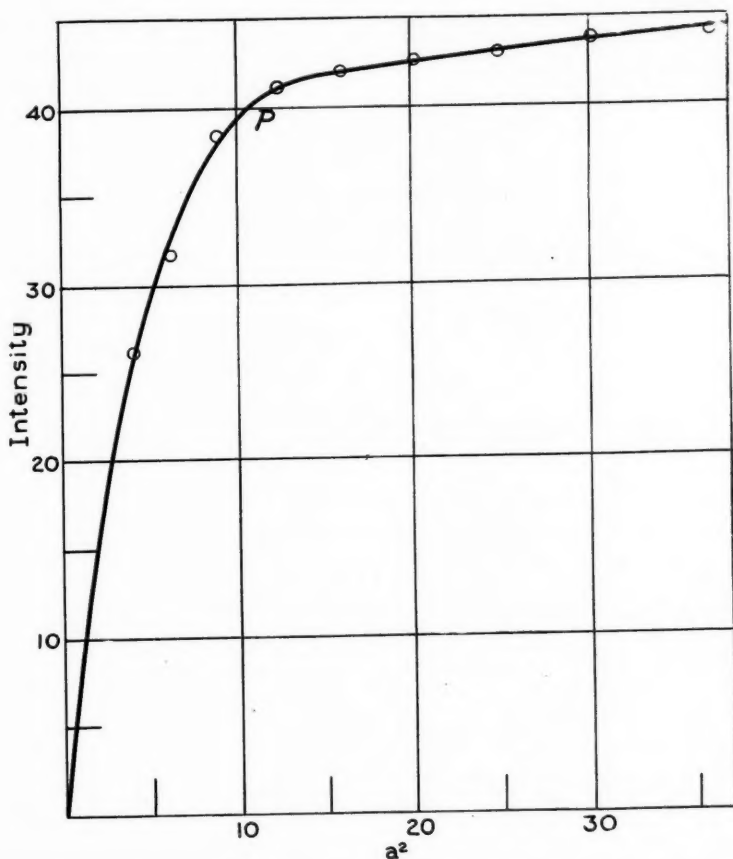
Fig. 9. Measure of the proportion of off-focus radiation to focal spot radiation for a particular tube.

whole face; whereas an exposure commensurate with the limiting error would give some indication of the actual off-focus radiation in proper proportion to the focal spot radiation. These three cases are shown, respectively, in Figures 8 (a), (b), and (c). While the amount of off-focus radiation will usually be but a small percentage of the focal spot radiation, it may

tube such that the aperture of the diaphragm system did not introduce more than 0.5 per cent maximum deviation in the flux density across a plane within the chamber. Ionization current readings were made as the diaphragm M was varied from a diameter of 0.4 to 1.2 centimeter. The curve in Figure 9 shows the intensity ($\propto$ to ionization current) plotted against a^2 ($\propto$ to area of M)

for a 200 K.V. Coolidge tube having a focus of radius about 0.4 centimeter. It is seen that the intensity increases very rapidly up to a point P which corresponds to the condition where the sharply defined focus just fills

differences in their respective off-focus radiation.

Referring to Curve II in Figure 5, showing the validity of the inverse square law, we have seen that the upper portion PQ
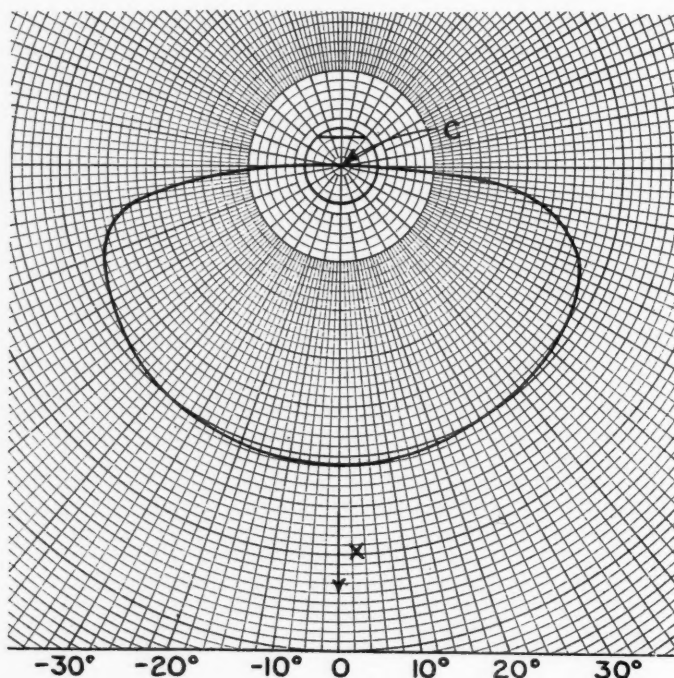
Fig. 10. Distribution of energy about 200 K.V. deep therapy X-ray tube target in a plane normal to the tube axis.

the aperture, while beyond this point the ionization increases very slowly and somewhat irregularly. Nevertheless, a continual increase is evident and no saturation value of the X-ray flux was indicated over the range studied. It is thus seen that for this particular tube and diaphragm system, the magnitude of this off-focus radiation can not be neglected.

It is probable that if two observers were to use, respectively, diaphragms M of 0.9 and 1.5 cm. diameter for such a tube some correction would have to be applied to make their measured r-units agree. Similar curves obtained for two other tubes showed

gave the nearest approach to the proper slope of —2. However, there is a very slight but definite divergence which may probably be attributed to the off-focus radiation, since the quantity of this radiation entering the ionization chamber varies with the distance B. Over the lower part PR of Curve I the slope is exactly —2, indicating good agreement with the inverse square law. (Equation (13).)

Behnken and Glasser have diaphragms M of 15 and 12.5 mm. diameter, respectively, placed in each case about 15 cm. from the target. Their X-ray tubes have focal spots of different size. It is therefore evident

that both may have quite a different ratio of on-focus to off-focus energy, and thus introduce discrepancies between their r-units. Again, Failla has no diaphragm close to his X-ray tube, but restricts his scattered radia-

Behnken's, and Glasser's) the radiation is taken off the target face at an angle of 45°, and at 90° to the cathode stream. Duane's diaphragm system is similar to that of Behnken and Glasser, except in being rec-
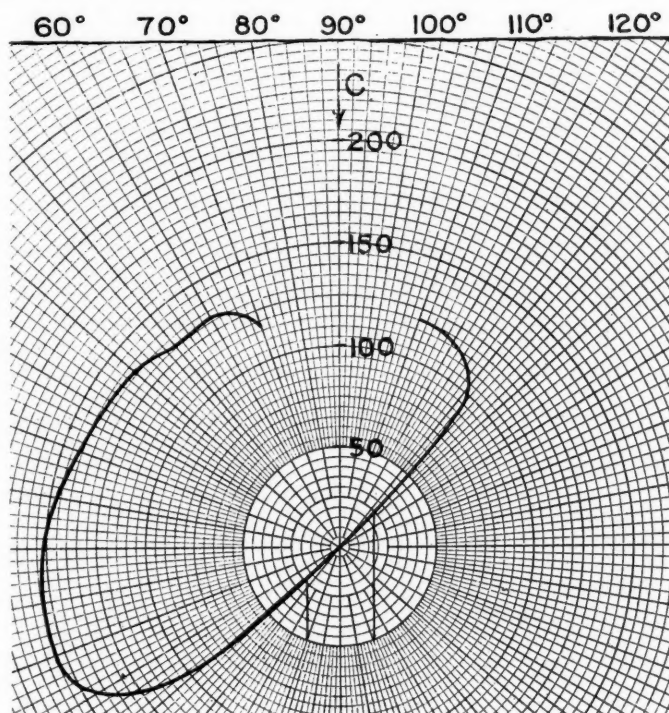
Fig. 11. Distribution of energy about target in a plane through the tube axis and the normal to the target face.

tion by a diaphragm some 30 cm. away from the focus. He has given a detailed discussion[23] of the changes in ionization due to varying the size and positions of his diaphragms. These differences in experimental technic require that proper allowance be made for off-focus radiation or else it must be completely shielded from entering the ionization chamber, which may be accomplished by using a diaphragm system wherein the focus always fills the aperture.

V. ERRORS DUE TO ENERGY DISTRIBUTION ABOUT THE TARGET

In three cases noted above (Failla's,

tangular. However, it is dissimilar in that the radiation is taken off the target at a small angle of some 10° to 15°, and, consequently, it is important to determine whether there is any possible error due to the uneven distribution of energy with angular direction about the focus.

The energy distribution about a massive target has been studied by Kaye,[24] Coolidge,[25] and others and is shown in Figure 10 for a 45° angle between cathode stream and normal to the target, the data being

[24]Kaye, G. W. C.: Proc. Royal Soc., London, 1910, LXXXIII, 189. Kaye found that as the angle between normal and cathode stream changed the distribution about the normal did not vary much.

[25]Coolidge, W. D., and Kearsley, W. K.: Am. Jour. Roentgenol, 1922, IX, 77.

[23]See Footnote 9.

taken from the paper by Coolidge and Kearsley and replotted on polar instead of rectangular co-ordinates. Figure 11 likewise shows the energy distribution about the focus in a plane perpendicular to the cathode stream.

by Duane, the tube tilted to an angle of about 35° and rotated about +70° to 75° from its normal position, and the cross-section of the beam photographed behind the second diaphragm. The resulting plate
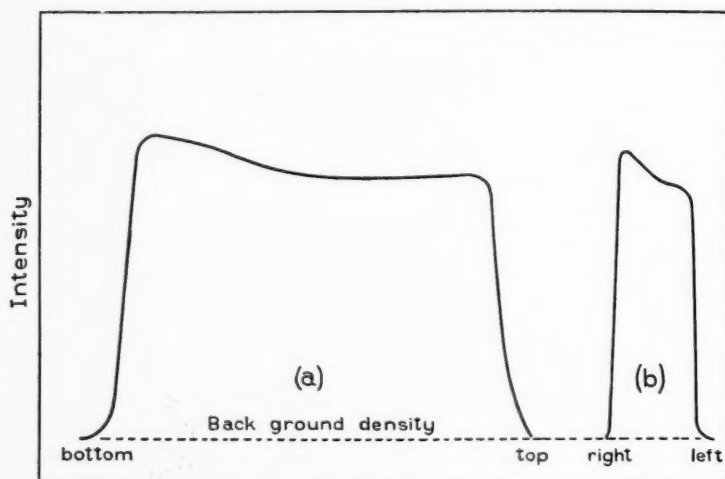
Fig. 12. Distribution of energy across a rectangular beam taken from the target at a glancing angle.

It is seen from the curves in Figure 10 that the distribution is nearly uniform in the direction used by Behnken, Glasser, and the Bureau of Standards. This is the direction in which radiation is usually taken in practice. At glancing angles to the target, however, the change in distribution is very rapid, so that the flux density across a plane x, as considered in Section II, should decrease appreciably in passing from one side of the beam to the other.

In Duane's case, where long rectangular slits are used, we should expect, therefore, an appreciable change in the flux density across the beam. Of course, if the diaphragms are sufficiently small such a change would be very small and could be neglected. A photographic determination of this effect was easily obtained. A rectangular diaphragm system was set up and carefully aligned so as to correspond to that used

densities are indicated in Figure 12, curve a being taken lengthwise of the rectangular diaphragm, and curve b crosswise. As should be expected, the lower part of the field is more intense than the upper and likewise the right side more intense than the left. These inequalities were obtained likewise in the opposite direction when the tube was rotated through —70° to 75°.

The variation in flux density here considered is entirely independent of that due to the cosine law; it is, however, possible that the two may be present at the same time. In an accurate comparison of the r-unit between two laboratories care must be taken that such errors are small enough to be neglected. An ideal standardization equipment would have the X-ray tube so constructed that the radiation is taken normally from the target.

In the author's first paper,[26] a careful study was made of the several methods used in measuring air ionization with particular reference to the accuracy of each method. As a consequence of the differences found, an improved method was tested and found to be satisfactory. In the present paper, the methods for obtaining the effective volume of air ionized have been analyzed, the results being summarized below. The next logical problem is that of analyzing the methods used in the comparison of the r-unit between the different laboratories having a standard ionization chamber. This problem is being undertaken at present at the Bureau of Standards.

SUMMARY

1. Previous investigators have assumed the X-ray tube focus to be a point source. Experiments described in the present article indicate that the assumption of a uniform and extended focus yields instead a more reliable determination of the r-unit when the distance between X-ray tube and standard ionization chamber is such that the focal spot area fills the diaphragm aperture. In this case the inverse square law is valid when applied to the distance between the X-ray tube diaphragm and the entrant diaphragm of the ionization chamber.

When the X-ray tube diaphragm is not filled the inverse square law should be used with the distance between the target and the entrant diaphragm of the ionization chamber. Off-focus radiation may impair, however, the accuracy of the results in this case.

2. The use of a limiting diaphragm close to the X-ray tube may introduce an error in the measurement of the ionization in the effective volume, this being due to the off-focus radiation entering the chamber. Such error may introduce discrepancies between the r-unit as established in various laboratories.

3. By having incorrect alignment of the diaphragm system serious error may be introduced in measuring the effective volume.

4. Due to non-uniform energy distribution about the target, the use of narrow rectangular diaphragms is inadvisable except under carefully determined conditions.

5. Using diaphragms of the same size, but having edges beveled at different angles, introduces no measurable difference in the ionization.

6. The discrepancy in measurements of the air volume under the conditions used by other observers is shown to lie within expected error.

Discussion of these problems with the various investigators cited has been very helpful. Recognition is due G. Singer and C. G. Malmberg, of the Bureau, for their assistance in the experimental work.

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[26]See Footnote 6.

X-RAY DIFFRACTION IN LIQUIDS

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TWO questions are considered in this paper: the correct interpretation of the inner (secondary) ring familiar in many liquid diffraction patterns, and a brief survey and evaluation of the possibilities of the photographic method of recording X-ray diffraction patterns of liquids.

When X-rays are transmitted through the alcohols or fatty acids or certain other long-chain compounds two diffraction maxima are produced. According to Stewart,[1] the outer ring, corresponding to the smaller spacing, is a measure of the cross-section of the molecule, while the inner one is associated with the length of the molecule. On this interpretation is based his theory of cybotaxis. Recently Thibaud and Trillat have stated[2] that only the outer ring is dependent on the size of the molecule while the inner ring is in every case due to general radiation and bears no relation to the length of the molecule. Obviously the question is of vital importance and should be settled before further studies of X-ray diffraction in liquids are undertaken.

The contentions of Thibaud and Trillat are, briefly, as follows: The inner (secondary) ring is due to a filtration of the general radiation by the liquid itself. If the specimen is less than 2.0 mm. thick, no inner ring is produced, and as the thickness of the specimen increases the intensity of the inner ring increases in comparison with that of the outer ring, since the K $\propto$ radiation is absorbed to a greater extent than is the general radiation. The diameter of the inner ring varies with the tube voltage, the ring diffusing toward the center as the voltage is increased. Other things be-

ing equal, the position of the inner ring is affected by the particular liquid used, since its size is a function of the coefficient of absorption of the liquid. Remarkable agreement is shown between the experimental values for the inner ring and the values calculated from absorption data. Thibaud and Trillat say little about the origin of this inner ring aside from the fact that it is due to general radiation. It must be diffraction produced by an identity period of some sort, however, and if it is not related to the length of the molecules then it must be related to the interplanar spacing corresponding to the cross-section. A similar ring is produced on pinhole diffraction patterns of steel. The inner edge of the ring is determined by the voltage on the tube and the outer edge by the absorption limit for silver. The diffraction of the general radiation is produced by the 110 planes of iron, the same which produce the most intense diffraction ring with K $\propto$ radiation.[3] It should be noted that Stewart considers in his first paper the possible effect of general radiation, and this point is discussed below.

It is a comparatively simple matter to choose qualitatively but conclusively between these two interpretations. If two isomers are chosen, each having the same number of atoms and therefore the same absorption coefficients, and X-ray diffraction patterns are obtained for both, using identical tube voltages and thickness of specimens, then according to Stewart the size of the inner ring will depend on the length of the molecule, while according to Thibaud and Trillat it will depend on the cross-section of the molecule. Fortunately in changing from a normal to a secondary or tertiary

[1] See several papers by Stewart and co-workers in *Physical Review* for 1927, 1928, 1929, and 1930.

[2] Thibaud and Trillat: Compt. rend., 1929, pp. 751, 907.

[3] Clark: Metals and Alloys, 1929.

TABLE I

READINGS TO ESTABLISH ACCURACY OF VISUAL MEASUREMENT
OF DIFFRACTION MAXIMA

| | Diameter of Diffraction Rings (cm.) | | | |
| | n-amyl Alcohol | | Secondary amyl Alcohol | |
Observer	Outer	Inner	Outer	Inner
1	2.40	1.40	2.32	1.16
2	2.41	1.38	2.33	1.09
3	2.40	1.38	2.32	1.08
4	2.41	1.43	2.30	1.10
5	2.40	1.38	2.34	1.10
6	2.40	1.38	2.35	1.10

TABLE II

THE DETERMINATION OF THE PROPER SPECIMEN-TO-FILM DISTANCE

Liquid	Cell Thickness	Diam. of Ring	Distance Specimen to Film	d (calc.)
n-butyl alcohol	1 mm.	2.25 cm.	7.15 cm.	4.55 A.
n-butyl alcohol	8 mm.	2.35 cm.	7.10 cm. (to near side of cell)	4.34 A.
			7.5 cm. (to center of cell)	4.57 A.
			7.9 cm. (to far side of cell)	4.80 A.
secondary amyl alcohol	2 mm.	2.25 cm.	7.20 cm.	4.69 A.
secondary amyl alcohol	8 mm.	2.32 cm.	7.1 cm. (to near side of cell)	4.41 A.
			7.5 cm. (to center of cell)	4.65 A.
			7.9 cm. (to far side of cell)	4.89 A.

alcohol the cross-section increases and the length decreases, hence the diameter of the inner ring will increase if the first theory is correct and should decrease according to the second theory.

EXPERIMENTAL

Preliminary experiments were undertaken to establish the most favorable conditions for obtaining clear, sharp diffraction patterns. Molybdenum radiation was found to be superior to copper radiation. Although the rings produced have a smaller diameter, they are sharper and offer a greater contrast to the background and may be measured with less percentage error, either with the eye or with the microphotometer, than can those produced by copper radiation. The liquids were held in a brass cell with retaining walls of thin mica. The mica produces a faint Laue pattern which is not to be confused with the measurement of the more diffuse liquid rings. The thicker the specimen the shorter the time required to obtain a satisfactory pattern, other things being equal. At 39 K.V. tube voltage an 8 mm. specimen requires six hours' exposure, while a 2 mm. specimen requires over 24 hours, using the same pinhole system. It is interesting to note that the thickness of the specimen apparently does not make the rings noticeably more diffuse. One might conclude from this that it is only molecules oriented at the interface which produce diffraction and the effective diffracting thickness remains constant as the thickness of the specimen is increased beyond a cer-

tain value. The fact that increased thickness decreases the time of exposure required refutes this conclusion, however, as do the data in Table II, indicating that the measurement of the plate-to-specimen distance

Their results are recorded in Table I. It is evident that the maximum error for the outer ring may be placed at 0.05 cm., or about 2 per cent, while the maximum error for the inner ring, which seems to be more

Fig. 1. n-amyl alcohol (35 K.V.).
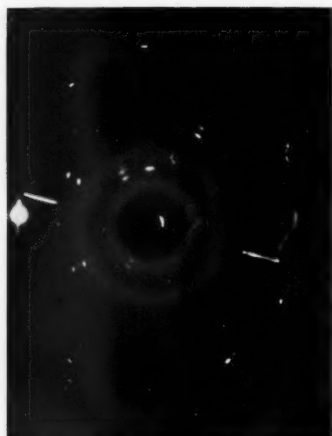
Fig. 2. ter-amyl alcohol (35 K.V.).

should be made to the center of the specimen. The effect of thickness of specimen on the nature of the diffraction should be subjected to further quantitative study. A thickness of 8 mm. was chosen for most of the experiments since that is the thickness used by Stewart in all his work and by Thibaud and Trillat in much of theirs. The radiation was filtered through one thickness of zirconia.

There are two main sources of error in the determination of the interplanar spacings. The measurement of the diameter of the ring is doubtless the main source, its magnitude depending on the diffuseness of the pattern and on the density of the negative. Some liquids produce much sharper diffraction rings than others. To establish the degree of accuracy attainable by measuring the diameter directly from the film, using dividers, two films were selected, one fairly dense and one fairly thin, and submitted to trained, independent observers.

difficult to measure, is 0.08 cm., or 7.3 per cent. The results indicate that it is reasonable to expect a degree of accuracy better than these maximum values from a trained observer. All these measurements were made on the most diffuse patterns (see Fig. 1). The percentage error may be halved on the patterns which are sharp (see Fig. 2). It is difficult to increase the accuracy greatly for this type of pattern by using a microphotometer, due to the general fogging of the negative which cuts down the contrast. The zirconia filter decreases this fogging considerably and further efforts are being made to eliminate it. It is entirely possible to obtain a microphotometer which, when used on films of ideal intensity, will reduce still further the error in direct measurement. The distance from specimen to film may be accurately measured. With a thick specimen the question arises as to the point in the specimen from which the distance should be meas-

TABLE III

Liquid	Thickness	Tube Volt.	Diam. of Rings		d (calculated)		Published Data*		Wave Length Inner Ring Å.
			Inner cm.	Outer cm.	Inner Å.	Outer Å.	Inner Å.	Outer Å.	
n-butyl alcohol	1 mm.	35 K.V.	....	2.25	....	4.55	11.1	4.4	....
n-butyl alcohol	8 mm.	35 K.V.	1.28	2.35	8.36	4.57	11.1	4.4	.39
Benzene	8 mm.	35 K.V.	1.28	2.25	8.36	4.77	....	4.7	.405
Tertiary amyl alc.	8 mm.	35 K.V.	1.20	2.18	8.89	4.92	8.5	5.05	.392
n-amyl alcohol	8 mm.	35 K.V.	1.38	2.41	7.93	4.46	12.6	4.4	.407
iso-amyl alcohol	8 mm.	33 K.V.	two rings						
iso-amyl alcohol	8 mm.	31 K.V.	three rings						
iso-amyl alcohol	8 mm.	29 K.V.	three rings						
Tertiary amyl alc.	8 mm.	27 K.V.	1.22	2.18	8.75	4.92	8.5	5.05	....
Secondary amyl alc.	8 mm.	27 K.V.	1.10	2.32	9.71	4.65	11.3	4.80	....

Maximum error: In outer ring (2%) = 0.1 Å., inner ring (7%) = .65 Å.
Probable error: 0.06 Å. .25 A

*Stewart and Skinner: Phys. Rev., 1928, XXXI, 1.

ured. This was established by obtaining the diffraction pattern for the same substance in a thin cell (in which case there is no question about the distance), determining the corresponding interplanar spacing and then comparing this value with the interplanar spacings calculated by assuming different film-to-specimen distances in the thick cell. The data for two independent determinations are set forth in Table II. It is evident that the distance should be measured to the center of the cell, which is the result most naturally to be expected. With this procedure the error in measurement is negligible.

The main advantages of the pinhole photographic method are the elimination of expensive apparatus and the possibility of obtaining direct, permanent, visible records. The accuracy attainable without the microphotometer justifies its use in many problems. By using a microphotometer the first advantage is lost but the accuracy may be doubled. With careful control of conditions it is probable that the photographic method will prove useful for all but the most precise work.

Using the procedure described above,

X-ray diffraction patterns were obtained for the liquids listed in Table III. With the help of Stewart's data liquids were chosen which would give the most marked diffraction maxima in the positions most useful in settling the point at issue.

DISCUSSION OF RESULTS

The first three listed in the table are in the nature of preliminary experiments. No inner ring is obtained for the thin (1.0 mm.) specimen, even with 54 hours' exposure, under the same conditions which produce such a ring in six hours with the 8.0 mm. specimen. This is in accordance with the observations of Thibaud and Trillat, but we do not feel that it is significant inasmuch as the diffracted radiation is so weak under these conditions anyway.

With normal butyl alcohol it is significant that the inner ring corresponds to a spacing quite different from the published value for the length of the molecule. Stewart and Morrow have demonstrated the appearance of a diffraction maximum at certain tube voltages due to general radiation and the position of this inner maximum for

n-butyl alcohol agrees reasonably well with that found by them.[4] Assuming that the inner ring is the result of the diffraction of the general radiation by the same interplanar spacing which diffracts the K $\propto$
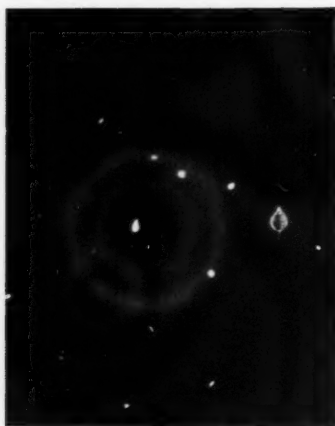
Fig. 3. Benzene (35 K.V.).

radiation to produce the outer ring (*i.e.*, the value corresponding to the cross-section of the molecule), we have calculated in the last column of Table III the wave length which would be so diffracted. This value (approximately 0.4 Å.) agrees reasonably well with the maximum effective wave length of general radiation at 35 K.V. as recorded by Siegbahn[5], if we allow for the fact that the peak would be shifted to a somewhat lower wave length by filtration by the zirconia and the liquid.

Stewart records only one diffraction maximum for benzene,[6] whereas at 35 K.V. we find two. Here again the inner ring is clearly due to general radiation (see Fig. 3).

The problem has been more systematically approached with the series of amyl alcohols listed. At 35 K.V. the inner ring is due to general radiation. As the voltage is decreased, the general radiation maximum becomes less marked. At 31 K.V. three rings were clearly indicated, reproducing the results obtained by Stewart when the exciting voltage was reduced in a similar manner. At the higher voltage the general radiation probably becomes intense enough to obscure the third, innermost maximum. At 27 K.V. the data indicate that the ring due to general radiation is absent and the inner ring is now the result of the diffraction of K $\propto$ radiation by a spacing corresponding to the length of the chain. It must be admitted that the quantitative agreement with the published values is not all that could be desired. At present we cannot account for the discrepancy. It is beyond the range of experimental error in some cases and so far as we know the specimens are pure. Qualitatively, however, the results are conclusive. At 35 K.V., in going from tertiary to n-amyl alcohol the diameter of the inner ring increases, therefore the spacing producing the diffraction must be the cross-section of the molecule—which decreases—and not the length. At 27 K.V., in going from tertiary to secondary amyl alcohol the diameter of the inner ring decreases, hence the spacing producing the diffraction must be that of the length of the molecule—which increases. The relative intensities of the two rings as brought out by the microphotometric curves is also convincing. For the alcohols at 35 K.V. the inner ring is much more intense than the outer, while at 27 K.V. the reverse is true, the two rings bearing about the same relative intensity indicated by Stewart's ionization curves.

As we interpret the statements of Thibaud and Trillat, the inner ring is due to general radiation at all voltages. They give data for copper radiation varying from 15 K.V. to 40 K.V. They have not published similar data for molybdenum radiation but state that similar results are obtained. It is quite evident from the data herein pres-

4Stewart and Morrow: Physical Rev., September, 1927, XXX, 232.
5Spectroscopy of X-rays, Oxford Univ. Press, 1925, p. 208.
6Physical Rev., June, 1929, XXXIII, 889.

ented that with a low enough voltage the inner ring is characteristic of the length of the molecule. These results are thoroughly in accordance with those of Stewart. Unfortunately, however, there was no possibility of applying Stewart's information on this point since he defined the proper voltage to use in terms of the primary voltage on his transformer rather than as the tube voltage. It has been demonstrated that the tube voltage must be considerably lower than that ordinarily used with molybdenum radiation in order to obtain characteristic liquid patterns.

SUMMARY

1. A preliminary survey of the possibilities and limitations of the photographic method of recording X-ray diffraction patterns of liquids has been made. It has been pointed out that only under very carefully controlled conditions are quantitative results obtained by this method reliable.

2. At a tube voltage of 33 K.V. or more the inner ring of the liquid diffraction pattern is produced by the diffraction and filtration of general radiation, and bears no relation to the length of the liquid molecule.

3. With a tube voltage of 27 K.V.— much less than the voltage usually used— the inner ring obtained is characteristic of the liquid under examination. It is, therefore, necessary to use this lower voltage in obtaining diffraction patterns for liquids.

ROENTGEN-RAY FINDINGS IN ERYTHROBLASTIC ANEMIA[1]

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THE CLINICAL ENTITY

ERYTHROBLASTIC anemia (3) is a hemolytic anemia occurring in infancy and early childhood, its most striking hematologic characteristic being the presence of an extremely large number of erythroblasts in the circulating blood; at times, the erythroblasts outnumber the leukocytes. The etiology is obscure. The Italian medical literature more fully treats this phase of the condition, which will not be discussed in this paper. The disease is apparently confined to a fairly definite clinical group. Only one subject (18) suffering with this condition is known to have reached adult life. A familial tendency has been observed, although this has not been the rule, and it has been noted wholly in children of Mediterranean ancestry, more especially Italians and Greeks. The patients present a peculiar appearance resembling the Mongolian race, and have a muddy yellowish discoloration of the skin. The cranium demonstrates thickening and the malar eminences are prominent.

The disease begins in early infancy with a moderate anemia. There is a pronounced early enlargement of the spleen, the increase in size being progressive. Leukocytosis is of varying degree, although as a general rule it is only moderate. There is a normal or slightly decreased fragility to salt solutions, although a slight increase has been noted in occasional instances. Reticulated cells are markedly increased in number; the red blood cells are diminished and usually range from 1,600,000 to 3,500,000 per cubic millimeter. The color index is low. The urine is dark colored and urobilin is present. Removal of the spleen causes an enormous increase in the erythroblasts, lasting for

years. There has been little definite improvement following the operation.

All of the cases noted in the literature which were examined by the roentgen rays demonstrated changes in some of the bones of the body, and all the investigators agree, in general, as to the appearances noted. In addition, roentgenograms of the bones in four cases, clinically diagnosed erythroblastic anemia, have been studied by us. Every case demonstrated some bone changes, the bone involvement varying somewhat in degree and distribution.

CLASSIFICATION

Further work on the classification of the anemias of infancy and childhood, associated with splenic enlargement, seems to be warranted, as no scheme satisfactory to clinicians, pathologists, and radiologists has been devised. The terms "primary anemia" and "secondary anemia," as used in the past, are not considered fully satisfactory by many investigators. The division of the anemias into the congenital and acquired types is sometimes confusing, as it is often difficult to establish the time of onset and the etiologic factors concerned in certain cases. For practical purposes, the terms "hemolytic" and "non-hemolytic" are often far more satisfactory. Karshner (22) has presented a classification which may be of value until further work on the etiology of the various anemias suggests a more logical one. Anemias are divided into three groups—

(1) Due to blood loss.
(2) Due to defective blood formation.
(3) Associated with increased blood destruction.

In most of the anemias, according to pathologists (22), there are changes in the bone marrow. Unfortunately, all the

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Fig. 1. Case 1, aged 15 years. Lateral view of the skull showing the thin inner and outer tables, enormous widening of diploë, with its characteristic porous appearance. The diploë adjacent to the outer table presents striations perpendicular to the tables of the skull.

Fig. 2. Case 2, aged 11 years. Skull similar to Case 1. There is a general prominence of the facial bones.

changes are not demonstrable on the roentgenogram, so that the radiologist fails to differentiate the three large groups of anemia founded on principles of pathologic physiology. And for this reason the investigator might ask, "Why has an attempt been made to study the roentgen-ray appearance of the bones in such a comparatively rare disease as erythroblastic anemia?" The reply is that the changes noted on roentgen-ray examination are not common in the anemias, but, when they do occur, they are often striking, and of material aid in the diagnosis.

As Whitcher (40) states in a recent article, the findings in erythroblastic anemia seem to justify its consideration as a definite clinical entity. For some time to come, however, cases will probably be classed un-

Fig. 3. Case 2, aged 11 years. Postero-anterior view.

Fig. 4. Case 4, aged 7 years. Lateral view of the skull showing early changes. Beginning perpendicular striation of diploë in posterior portion of the parietal bones.

der the more general term "Von Jaksch's anemia."

HISTORY

Cooley and Lee (5), in 1925, described a series of five cases of anemia, with spleno-megaly and peculiar bone changes, in chil-

radiologist to clearly describe the roentgen-ray appearance of the bones. He examined the cases described by Cooley in 1925. Karshner (22), in 1928, reviewed the roent-genograms of Cooley's fifth case and added her findings in two additional cases of erythroblastic anemia. Friedman (12), in

Fig. 5. Case 1, aged 15 years. Trabeculations throughout the pelvis and upper femora.

dren. In 1927, Cooley (4) classed these cases as a peculiar type of Von Jaksch's anemia. Later, in 1927, Cooley, Witwer, and Lee (7) published case histories of their original five cases and two additional cases studied elsewhere. The condition was termed "erythroblastic anemia" by Cooley (3) in 1928. At that time he clearly dif-ferentiated what he considered to be three hemolytic anemias of childhood, and em-phasized that congenital hemolytic icterus, sickle-cell anemia, and erythroblastic anemia were all rather closely related, not only in symptomatology, but probably also in funda-mental etiology.

Reynolds (29) appears to be the first

the same year, described the roentgen-ray findings in three cases and the necropsy find-ings in a fourth case. The title of his paper was, "Osseous Changes in Hemolytic Icterus," but a study of his case reports demonstrates that his patients had all the characteristic findings typical of the clinical group termed "erythroblastic anemia." Hitz-rot (18), in 1928, reported four cases, one of which had been reported by Stillman (36) as Von Jaksch's anemia in 1918. In the same year Whipple, Reeves, and Cobb (39) added two more carefully studied case reports. In 1930, Whitcher (40) reported three cases, but did not include roentgen-ray studies. Diamond (9), in 1929, mentioned

Fig. 6. Case 1, aged 15 years. Trabeculations of the lower dorsal and lumbar vertebræ.

Fig. 7. Case 3, aged 4 years. Striations throughout the pelvic bones.

the three anemias noted by Cooley in 1928. He termed them "congenital anemias," instead of "hemolytic anemias" as designated by Cooley. Diamond reviewed fourteen cases of the erythroblastic type, one of the sickle-cell type, and four of the congenital hemolytic type. Vogt (38) at the same time correlated the clinical, pathological, and roentgenologic findings and demonstrated changes in the skull and long bones.

PATHOLOGY

At least six necropsies which included studies of the bones are known to have been performed, and several other studies of spleens removed at operations can be found in the literature. A discussion of the fibrotic changes found and their similarity to other splenomegalies found in children need not be discussed here. In general, the necropsies agree in the description of the gross findings in the skull and long bones. Cooley,

Witwer, and Lee (7) presented the necropsy findings of skull, long bones, and viscera of two of Cooley's early cases. Friedman (12) added a third, and Karshner (22) mentions a fourth necropsy. One of Diamond's series came to autopsy. Schultz's (33) necropsy of a case, reported clinically by Cooley, is fairly representative of them all, and his findings are of particular interest to the radiologist.

The fundamental changes noted in the long bones and the skull vault were similar in character, in spite of the differences in osseous development. The long bones showed thinning of the cortex. Schultz states that there was a partial replacement of cellular marrow by cellular connective tissue of the osteoid type, and he interpreted these changes as due to an aplasia of the erythroblastic marrow and a hyperplasia of the leukoblastic marrow. The actual cellu-
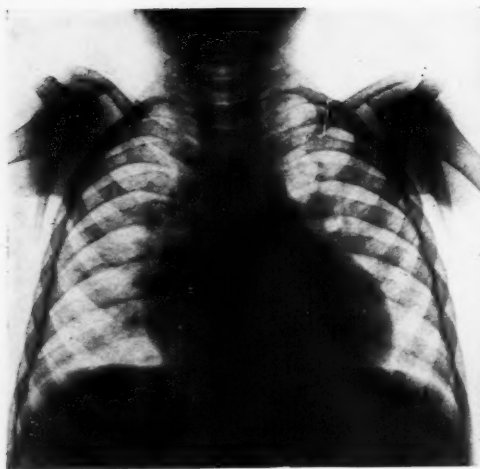
Fig. 8. Case 3, aged 4 years. Trabeculations of the ribs, scapulæ, and clavicles. These are shown best on the original roentgenogram.

Fig. 9. Case 1, aged 15 years. Lower cervical and upper dorsal vertebræ and upper ribs demonstrate trabeculations.

lar connective tissue of osteoid type was taken as evidence of beginning exhaustion of the hyperplastic process present.

The intra-membranous bones of the skull participated in the same hyperplasia of leukoblastic marrow as characterized the long bones. The same absence of erythroblastic hyperplasia and increase in the amount of spongy trabeculated bone was observed in the frontal, parietal, temporal, and occipital bones.

Cooley believes that the changes in the bones of the skull are a part of the same process involving the hemopoietic system as a whole. He explains that these changes in the bones are the result of the reaction of the marrow to prolonged over-stimulation, the marrow having been over-stimulated to compensate for the chronic hemolysis. The hyperplasia of the marrow begins before the cortex is firm enough to stop the overgrowth of the marrow. In the earlier stages and less severe cases, the porous appearance in the roentgenogram seems to represent marrow hyperplasia. In the terminal stages, the pronounced striation indicated replacement of the exhausted bone by new bone as found

at necropsies. Cooley does not believe that bone change is primary.

In summary, it is important to state that necropsies performed independently, in different medical centers, agree that there is a—

(1) hyperplasia of the marrow of the long bones;

(2) general thinning of the cortex of the long bones;

(3) hyperplasia of the diploë of the bones of the cranial vault;

(4) thinning of both inner and outer tables of the skull;

(5) trabeculæ of connective tissue and osteoid tissue in the medulla of the long bones.

CLINICAL STUDIES

Full clinical case reports are to be discussed by another investigator. Of the four cases studied, the syphilitic background in one case, and the question of a tuberculous history in a second, are worthy of detailed discussion. After careful consideration, study, and laboratory investigations, the four patients roentgenographed have been considered by clinicians to be cases of

erythroblastic anemia. They all presented the fundamental picture of the condition described at the beginning of this paper.

Wollstein and Kreidel (41) have very

ple and his co-workers two cases. We have reviewed the films of four cases studied clinically by the Department of Pediatrics, and roentgenologically by the Department

Fig. 10. Case 2, aged 11 years. Lateral view of lower humerus and upper radius and ulna demonstrating trabeculation near the metaphyses and thin cortices.

Fig. 11. Case 2, aged 11 years. Antero-posterior view of same case.

recently presented excellent clinical studies of nine cases.

ROENTGEN-RAY STUDIES

The results of the roentgen-ray examinations of the bones can be found in the literature. Diamond and Vogt present the results obtained in fourteen cases, Cooley seven cases, Hitzrot four cases, Friedman three cases, Karshner two cases, and Whip-

of Radiology, Yale University, School of Medicine.

Case 1. Male. Two series of roentgenograms taken at age of 15.

Case 2. Female. Two series of roentgenograms taken at ages of 9 and 11, respectively.

Case 3. Male. Three series of roentgenograms taken at ages of 3 and 4, respectively.

Case 4. Male. Four series of roentgeno-

grams taken at ages of 5, 6, and 7, respectively.

The series enumerated above were by no means complete roentgen-ray examinations to co-operate and to return for further studies.

Pathologic change was not noted in all of the long bones roentgenographed
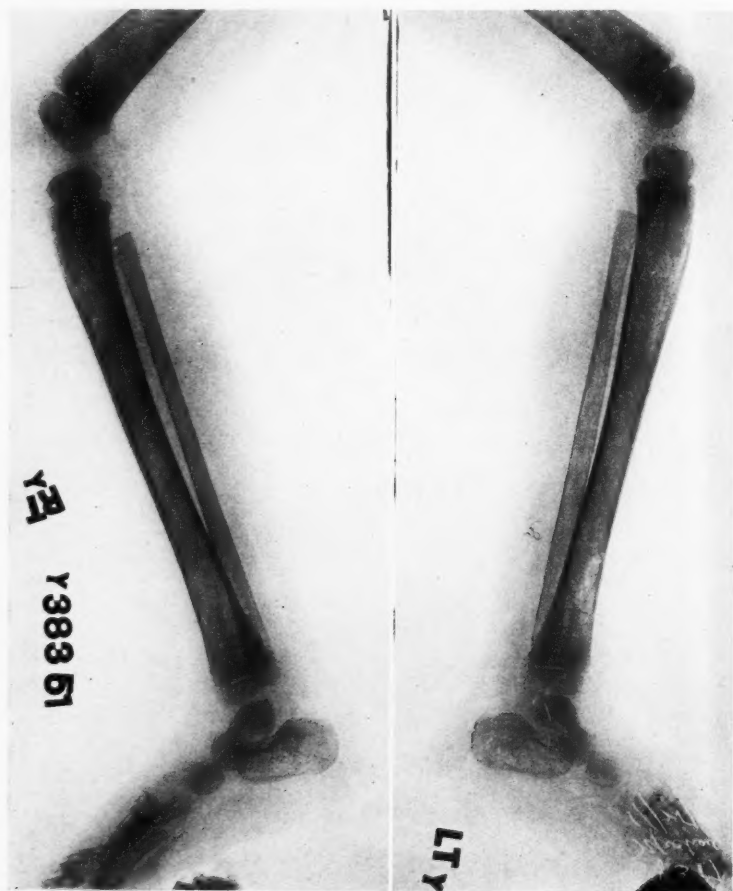
Fig. 12. Case 3, aged 3 years. Lateral view of both tibiæ and fibulæ, demonstrating thin cortices and transverse striations in the metaphyses.

of all of the bones of the body, because at the time of these examinations the diagnosis of erythroblastic anemia had not been established. More complete examinations have been made when possible. One child died and a necropsy was not obtained. Two of the dispensary patients have, so far, failed

All the skulls radiographed demonstrated changes in the cranial vault, while several of the spines, scapulæ, and pelvic bones demonstrated definite changes. The ribs of several cases showed evidence of pathologic change.

A careful study of the roentgen-ray find-

ings noted in the literature and the four cases studied by us demonstrated—

1. Thickening of the medullary portion

Several authors have described this as a spongy or porous appearance.

4. Striations perpendicular to the tables
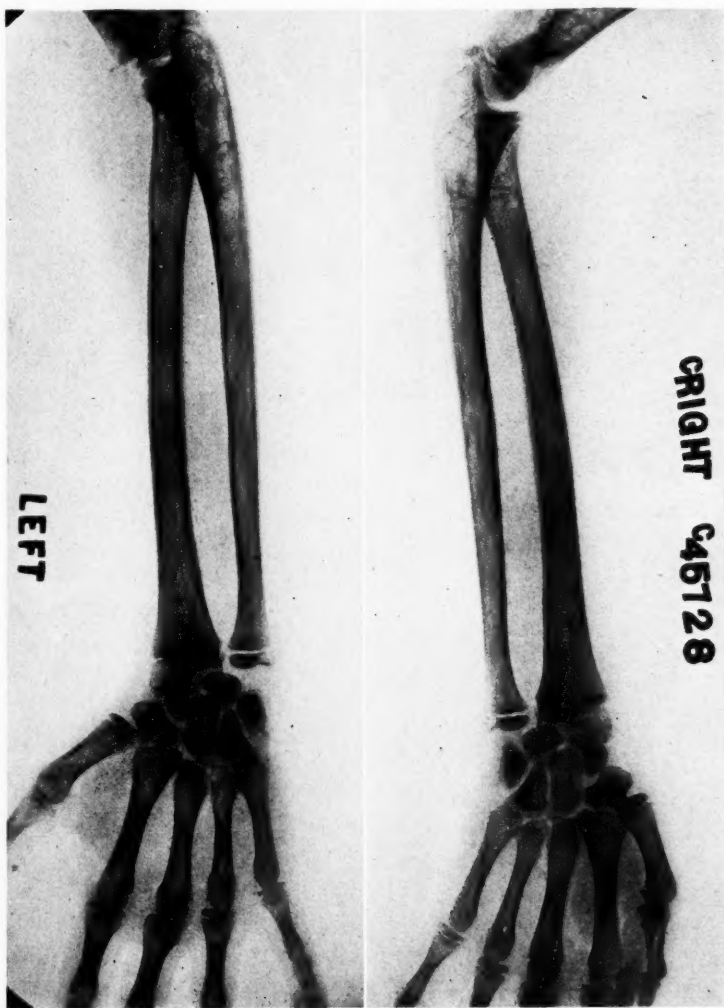
Fig. 13. Case 1, aged 15 years. Irregular striations of the metaphyses. No widening of the metacarpals is demonstrated.

of the frontal, parietal, temporal, and occipital bones.

2. Thinning of the inner and outer tables of the bones of the skull vault.

3. A mottled appearance of the medullary portion of the cranium in the earlier stages.

of the skull in the later stages. The diploë gradually assumes a thickness equal, at times, to as much as four times its normal width.

5. Irregular trabeculations in the pelvis, vertebræ, ribs, clavicles, and scapulæ. This

appearance is apparently due to new bone formation. There is evidence of slight rarefaction within the trabeculated areas, which has been described as a porous appearance. This is evidently due to localized destructive bone changes.

6. Definite thinning of the cortex of the long bones. This is an important and rather constant finding.

7. Rarefaction of the shafts of the long bones. The medulla of the long bones demonstrates increased radiability. This characteristic is well illustrated and described by some authors as a transparent medulla.

8. Trabeculations of the medulla of the long bones, more marked in the metaphyses. They appear as sharp and finely pencilled trabeculæ near the ends of the bones. Some authors have described them as trabeculations perpendicular to the cortex, but this we have found not to be the rule. The trabeculation may affect all of the bones of the body.

9. Normal joints. No pathologic change has been noted to involve the joint surfaces or spaces.

10. No periosteal elevation. Periosteal involvement is not recorded.

11. Absence of pathologic fractures. Spontaneous fractures were not noted in any of our cases, nor did any of the cases reviewed in the literature mention them. In spite of the evidences of bone destruction, the rapid compensatory bone production following has evidently prevented pathologic fractures.

Several authors have noted widening of the metacarpals and metatarsals and rarefaction of their shafts. While these changes probably do occur, we have not found them in our cases.

A few investigators describe a thinning of the inner table of the skull vault, and a thickening of the diploë and outer table of the skull. The necropsies performed dem-

onstrate that both the inner and outer tables are thinned, and a study of roentgenograms of the skull seems to confirm the necropsy findings. Occasionally it is difficult to visualize the outer table because of its extreme thinness.

DIFFERENTIAL DIAGNOSIS

At the present time, we cannot state that the roentgen-ray findings in the bones are characteristic of erythroblastic anemia alone. Two other anemias, characterized as hemolytic by Cooley, namely, sickle-cell anemia and congenital hemolytic anemia, are said to present similar bone changes. Diamond (10) states that the changes are similar but not as marked. He says in part: "The roentgenologic changes are not characteristic of any one disease but may result from any process in which there is a moderately severe and prolonged anemia in infancy or childhood, with resultant hyperplasia of the bone marrow tissue. The only cases which fulfill this requirement that I know of are those of erythroblastic anemia, sickle-cell anemia, and congenital hemolytic anemia."

Grulee (16) and Gänsslen (13) concur in the opinion that bone changes are not characteristic of erythroblastic anemia. Cooley insists that they are, however, indicative of a chronic hemolytic process belonging to the general group of hemolytic icterus. He points out definitely that non-hemolytic anemias, rickets, and syphilis show no bone changes similar to those noted in the hemolytic anemias.

The presence in the blood picture of the characteristic cell in sickle-cell anemia would serve effectually in establishing a diagnosis. With but two exceptions, all cases noted in the literature occurred in patients of negro or mulatto extraction.

Congenital hemolytic anemia is not limited to children of Mediterranean ancestry. There are more reticulated red blood cells in

this disease than in any other. Increased fragility of erythrocytes to hypotonic salt solutions is common. The spleen demonstrates only slight enlargement, even after marked progression of the disease. Removal of the spleen brings about marked improvement—hemolysis stops and anemia and jaundice disappear.

The clinical and laboratory findings of the three anemias designated as hemolytic in type are, therefore, sufficiently different to clearly distinguish them.

All the diseases of infancy and childhood which present enlargement of the spleen must be differentiated from erythroblastic anemia. The anemia described by Von Jaksch in 1889, the chief characteristic of which was the large number of immature cells of all types in the blood, is now regarded by many observers as a very doubtful clinical entity. Cooley (4) considered erythroblastic anemia to be a peculiar type of this disease, as late as 1927. He has since that time altered his opinion.

The bones in erythroblastic anemia do not demonstrate periosteal elevation. In leukemias, periosteal elevation of the long bones is usually noted. The character of the leukocyte counts is, if course, important clinically in establishing the type of leukemia and in following the progress of the disease.

Karelitz (21) reported a case of myeloid leukemia with periosteal elevation and some cortical erosion.

Rolleston and Frankau (30) have described thinning of compact bone, thinning of the ribs, and enlargement of cancellous spaces in a case of acute lymphatic leukemia. Pendergrass and Bromer (27) have noted an increase in the width of the zones of temporary calcification in this disease.

Gaucher's disease (8) presents enlargement of the spleen. Splenic puncture and demonstration of the peculiar endothelial cell masses (Gaucher cells) may establish a

Fig. 14. Case 1, aged 15 years. Irregular trabeculation of metaphyses at elbow. No joint involvement. No periosteal elevation.

diagnosis. There is usually a leukopenia. According to Steiner (34), Pick believes it to be a skeletal disease. Necropsy findings have demonstrated Gaucher cells in the bone marrow, liver, spleen, and lymph nodes. The long bones have been expanded and their cortices thinned; periosteal involvement and pathologic fractures have been noted,

and a lumbar kyphosis and compression of vertebral bodies have occurred. No changes in the skull have been observed.

Fischer (11) has made a careful study of the roentgen-ray findings in Gaucher's disease. He has presented three cases in which the disease was confirmed by histologic sections following splenectomy. Of seven cases, six showed distention and flask-shaped deformity of the distal end of the femur, while in five cases a rarefaction of the medulla of the femur was also demonstrable. The deformity of the distal end of the femur is regarded by Fischer as typical of Gaucher's disease.

Steiner (34) found nine cases of the splenohepatomegaly of Niemann Pick in the literature. The progress of the disease was rapid. Splenic punctures demonstrated typical foam cells. A peculiar case in a girl of five was observed, with cranial and skeletal bone involvement.

The onset of symptoms in Banti's disease (20) occurs as a rule later in childhood, and it should not be confused with erythroblastic anemia.

There are several cases of thrombotic and parasitic splenomegaly reported in the literature, occurring in early childhood, so unusual that an attempt to differentiate them would be confusing.

Holmes and Ruggles (19) state that a true periostitis usually appears as a deposit of new bone upon a cortex of normal appearance, and that periosteal new bone formation may be due to any form of irritation. In early life, syphilis, rickets, and scurvy present periosteal change in the bone which in itself serves to differentiate them from erythroblastic anemia. All three present different endochondral changes in the long bones, which aid further in distinguishing them.

The tuberculous and pyogenic processes which usually occur later in childhood present changes characteristic of bone and car-tilage destruction which have been fairly well established. The periosteal changes so often noted in the pyogenic forms of destruction readily exclude erythroblastic anemia.

Pathologic changes in skull roentgenograms must be differentiated in various diseases.

The skull is frequently involved in syphilis, most often the bones of the vault and face. They may become affected in any of the stages of the disease. According to Schüller (32), the formation of syphilitic granulation tissue has its origin in the periosteum, dura, mucous membrane, or bone marrow. The outer table of the frontal, temporal, and parietal bones often demonstrates localized areas of increased density due to the deposition of granulation tissue between the periosteum and outer surface of the bone. The medullary spaces of the diploë are widened, so that roentgenograms demonstrate a rarefied appearance.

Gummata of the skull produce an appearance of irregular bone destruction and surrounding areas of sclerosis. Occasionally there is formed a sclerosis of the diploë, progressing in some areas to a condition of eburnation, along with massive thickening of the bone. The manifestations of hereditary syphilis in the skull are too well known to deserve mention here. In erythroblastic anemia the perpendicular striations in the diploë and thinning of both tables throughout the cranial vault should not be confused with the irregular syphilitic changes described by Schüller. Early changes, it is true, cannot be differentiated by roentgen-ray examination.

Hyperostoses, localized to certain portions of the cranial vault, have been noted in cases of brain tumor. The pressure of an endothelioma of the dura mater against the vault is often associated with a definite clinical history and symptoms.

Under the heading "hyperplastic osteitis," Schüller considers syphilitic hyperostoses,

hyperostoses occurring in icterus, the ossifying osteitis occurring in leukemia, malignant tumors, chronic arsenic and phosphorus poisoning, chronic alcoholism, pregnancy, and osteomalacia. He admits that not much is known concerning the skull changes noted in these conditions with the possible exception of syphilis. On the other hand, it is well known that osteitis deformans and osteitis fibrosa produce widespread bone changes. Practically all these conditions are unknown in infancy and early childhood and, therefore, need not be considered.

The majority of primary and metastatic tumors of the skull are not found in infancy and early childhood. Chloroma, however, does occasionally present an appearance easily confused with the skull of erythroblastic anemia. Karshner (22) states that although chloroma was formerly classed with tumors it is now thought to be related to, if not a form of, acute leukemia. She states that the clinical symptoms, blood picture, and pathologic findings of the two are frequently identical. Schüller (32), Allison (2), Gould and Le Wald (15) consider it as an entity. The localization of bone proliferation about the orbit, the widening of the sutures of the skull, irregular mottling of the skull vault and of the shafts of the long bones, the periosteal proliferation, and the formation of greenish infiltrations of the lymph nodes are said to be diagnostic of chloroma. Because of the difference of opinion among pathologists concerning this condition a more definite differentiation cannot be presented at this time. In two instances when films of skulls, clinically and roentgenologically diagnosed erythroblastic anemia, were shown, the possibility of chloroma was suggested by physicians present. A complete examination of all of the bones of the skeleton is, therefore, advised.

CONCLUSIONS

1. A review of the literature reveals forty-seven cases of the clinical entity termed "erythroblastic anemia."

2. Roentgen-ray examinations in erythroblastic anemia demonstrate peculiar changes in the bones of definite value in confirming the clinical diagnosis.

3. The roentgen-ray findings in the bones in four additional cases of erythroblastic anemia are presented.

4. Necropsies of six cases have been made in various medical centers. Necropsy reports tend to confirm roentgen-ray findings.

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VISUALIZATION OF THE PELVIC VISCERA

IODIZED OIL AND PNEUMOPERITONEUM COMBINED IN GYNECOLOGY[1]

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WE have used pneumoperitoneum in our study of the female pelvic viscera since 1923, utilizing the transuterine or transabdominal route of inflation in 470 patients. In 150 of these, iodized oil (lipiodol) has been employed in combination with gas for intra-uterine instillation. There has been no accident or untoward result in this series of patients, and in none of those who were operated upon subsequent to the diagnostic procedure was evidence of peritoneal irritation or inflammation found. This can probably be attributed to the careful selection of patients, the judicious choice of route of inflation, careful asepsis and antisepsis, and after-care.

Discomfort, which more or less attends this mode of examination, has been minimized by the adoption of a routine which has been followed for some time, almost without exception. The patient is hospitalized, and given a low soapsuds enema about one hour before examination. This is followed by a hypodermic injection of 1/6 grain of morphine and 1/150 grain of scopolamine one-half hour before the examination. The eyes are covered with a towel, and attendants are instructed not to converse with or disturb the patient in any way. She is kept quiet in a darkened room and is disturbed only to void urine just before being transported to the X-ray room on a cart and placed in position on a table especially constructed for pneumoroentgenography (1).

The following routine, described in our previous publications (2), is then carried out. Briefly, it consists of:

(a) Dorsal lithotomy posture, with hips slightly elevated;

(b) Insertion of modified Graves' vaginal speculum;

(c) Disinfection of vagina and cervix with 2 per cent mercurochrome solution;

(d) Introduction and adjustment of a special self-retaining canula set (3);

(e) Pneumoperitoneum induced by the transuterine or transabdominal route, the method of choice being determined by the gynecologic condition;

(f) Intra-uterine instillation of 5 c.c. of iodized oil through self-retaining canula;

(g) A single roentgenogram, made in the dorsal posture;

(h) The patient at this stage placed in the partial knee-chest position, and, with the instrument remaining *in situ*, the instillation of an additional 2 c.c. of iodized oil;

(i) The patient now lowered to the final position on the table and films taken (1);

(j) After an interval of five minutes the taking of another film;

(k) In some instances, where tubal patency is still in doubt, the taking of additional films eighteen or twenty-four hours later, the instrument in this case having been removed.

The after-care of the patient is important. She is transported back to bed on the cart, care being taken that her head and shoulders are kept lowered, and in case upper abdominal discomfort exists, the hips are elevated. The patient is kept flat in bed for from eighteen to twenty-four hours to avoid discomfort on arising. Although some patients do complain of minor abdominal discomfort and shoulder pain for a day or two, the great majority go about their

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Fig. 1-*A*. Right hydrosalpinx containing "pearl cluster" of lipiodol.
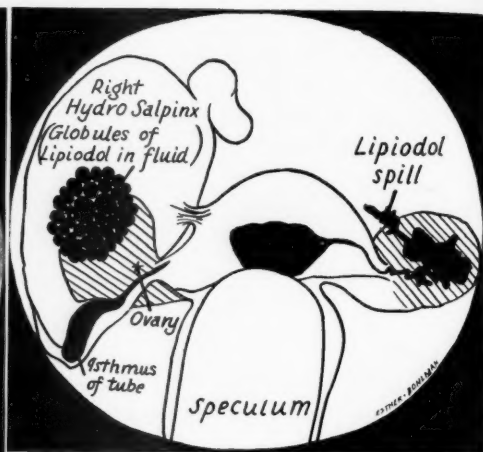
Fig. 1-*B*. Explanatory diagram of film shown in Figure 1-*A*.

duties undisturbed. We have seen no general systemic or local reactions, such as fever, vomiting, bladder disturbances, or other evidence of peritoneal inflammation, following this routine.

IODIZED OIL *vs.* THE COMBINED METHOD

We have been interested in statements in the literature reporting on the diagnostic value of iodized oil alone in pelvic diagnosis (4, 5, 6). That fibroids, cysts and other pelvic tumors can readily be diagnosed by this means, has not been verified in our experience. We have previously shown and emphasized, however, that these same conditions can be clearly recognized and differentiated by pneumoperitoneum (7). In order to estimate the diagnostic value of the methods separately and in combination, we have compared roentgenograms in which iodized oil alone has been used, and also in combination with gas, in the same patient. In no instance were the films of the intra-

uterine lipiodol instillation alone of greater value than to show the size and shape of the uterine cavity, and the filling, or failure to fill, of the tubes. Peritoneal spill was not commonly present, probably because only 5 c.c. of the oil was used at first and because the film was taken promptly. Even when spill is present to a marked degree, we are unable to attribute much value to this method, other than to determine tubal patency, size and shape of the uterine cavity, and points of tubal obstruction. Even this latter bears careful interpretation since the arrest of the iodized oil at any point in the tube may be caused by spasm as well as by pathologic stenosis (8).

On the other hand, the films in the partial knee-chest posture after combined pneumoperitoneum and intra-uterine lipiodol instillation rarely failed to show the exact pelvic status clearly. It is uncanny how completely and how accurately one may often record the pelvic pathology in the roentgen film. The combined use of lipiodol and pneumoperitoneum permits one literally to look into the pelvis without incision or the use of the abdominoscope.

DIAGNOSIS OF HYDROSALPINX

The recognition of closed Fallopian tubes offered one of the first and most obvious uses of a contrast medium in gynecology. Large accumulations of the opaque oil in the region of the distal ends of the tubes could be easily interpreted. However, some cases yielded puzzling results as to whether the oil was retained in the tubes or spilled into the peritoneal cavity, because regular globules of the oil, resembling pearls, were to be seen in the pelvis. One of the most striking instances of this which we have seen is illustrated in Figure 1-*A*.

CASE REPORT

Mrs. F. G., aged 25, was seen July 10, 1927, because of a sterility problem. Her chief complaints were menorrhagia, dysmenorrhea, and backache. Her last period had been June 20, 1927. Hühner's test (on July 16th), two hours post-coitum, revealed many motile spermatozoa in the vaginal pool and also in the aspirated endocervical mucus. She failed to menstruate in August but menstruated September 3d, profusely, for 48 hours. Examination (on September 8th): Uterus and adnexa negative (patient unfavorable for bimanual examination because of rigidity). Patency test was performed November 9, 1927, five days after cessation of menses, during which the manometric pressure rose to 200 mm., but dropped promptly to 80 millimeters. Transuterine pneumoperitoneum was induced, using 1 liter CO_2, and 5 c.c. lipiodol was instilled into the uterine cavity. Films were taken in the prone and partial knee-chest postures. The films disclosed the following: At least one tube patent, the gas passing readily into the peritoneal cavity. The left was evidently patent as the right was occluded. Both ovarian contours were within the range of normal. The right

ovary, while of normal size, was somewhat dense. There was a large mass in the right posterior half of the pelvis, the size of a lemon, which had the appearance and the consistency of a cyst. The right tube was dilated immediately beyond the isthmus, for a distance of approximately 2 cm., although the interstitial portion appeared of normal size. The lipiodol had collected in the right half of the pelvis and just above the dilated portion of the tube, in globules the size of peas, all massed together like a pearl cluster. From its location within the confines of the cystic mass, and from the fact that the opaque medium was in globules which had not coalesced, a tentative conclusion was drawn that the globules of lipiodol were within the cystic mass, having been forced through a small opening in the tube. Hydrosalpinx had to be considered.

Subsequent films, taken twenty-four hours later, showed a complete absorption of the gas, but the lipiodol, which previously presented the appearance of a "pearl cluster," had consolidated into one dense mass instead of being distributed throughout the peritoneal cavity. This appeared to confirm the previous findings that the opaque substance entered the cystic mass.

The patient was re-examined bimanually the following day, under gas anesthesia, and the mass palpated, the findings being corroborated by a colleague in consultation. Patient was operated on November 12, 1927.

Operative report.—The uterus and left adnexa appeared normal. The right tube was greatly enlarged, pear-shaped, transparent, containing fluid and an oily substance. This was unquestionably the lipiodol which had been instilled through the uterus a few days previously. There was no evidence of intraperitoneal irritation from the lipiodol spilled through the opposite tube. The right ovary contained a hemorrhagic corpus luteum. The hydrosalpinx and right ovary were removed.

Fig. 1-*D*. Explanatory diagram of Figure 1-*C*.

Fig. 1-*C*. Hydrosalpinx after surgical removal. Note retained coalesced lipiodol.

REPORT OF THE PATHOLOGIC LABORATORY

Hydrosalpinx—parovarian cysts of the Fallopian tube.

Gross.—The specimen is a large, egg-shaped mass, measuring $9 \times 5.5 \times 5$ cm., and at one end is a curved piece of tube 3.5×0.5 cm., swelling to a diameter of 2.0 centimeters. From this point the diameter increases to 5.5 cm., and at the other end of this egg-shaped swelling are a number of adherent fimbriæ, close to which are two cysts 2.5 and 1.0 cm., respectively. The large cyst, apparently, is made up of a markedly distended tube, and the wall is parchment-like, with a smooth lining. This cyst is filled with clear fluid and at the bottom is 2 c.c. of a heavy yellow oily substance. In the isthmic portion, as seen from the inner portion of the cyst, is a large valve-like fold separating off a small cystic space from the main cavity. The two easily communicate and within the smaller

cavity are a number of linear folds which course out into the main cyst. Where these join is a small opening through which a fine probe can be passed to the isthmic portion of the Fallopian tube, to a point about 1.0 cm. from the end of the tube. At the other end of the cyst there is no apparent opening to the fimbria.

Microscopic.—Sections from the thin wall of the tube show a thin, fibrous tissue membrane, lined on one side by a single layer of flattened epithelial cells. The epithelial cells of the fimbriæ of the tube are large and have a relatively clear cytoplasm. While the lining of the large cyst resembles that of a parovarian cyst, it probably represents the wall of a markedly distended tube.

The post-operative condition was satisfactory.

In this case the interpretation was especially difficult for the following reasons: (1) The "pearl" formation was unilateral; (2) the opposite tube was clearly patent to both CO_2 and to lipiodol, the latter appearing unmistakably as a "spill" on all of the films; (3) the cystic mass on the side where

the "pearl" formation occurred greatly resembled an ovarian cyst.

In the study of the films it was granted that the oil was definitely in a fluid medium, this causing it to assume the pearl-like ap-

It was by this process of elimination that the diagnosis of unilateral hydrosalpinx was made before operation, which diagnosis was substantiated at laparotomy, a congenital hydrosalpinx, non-inflammatory in nature,
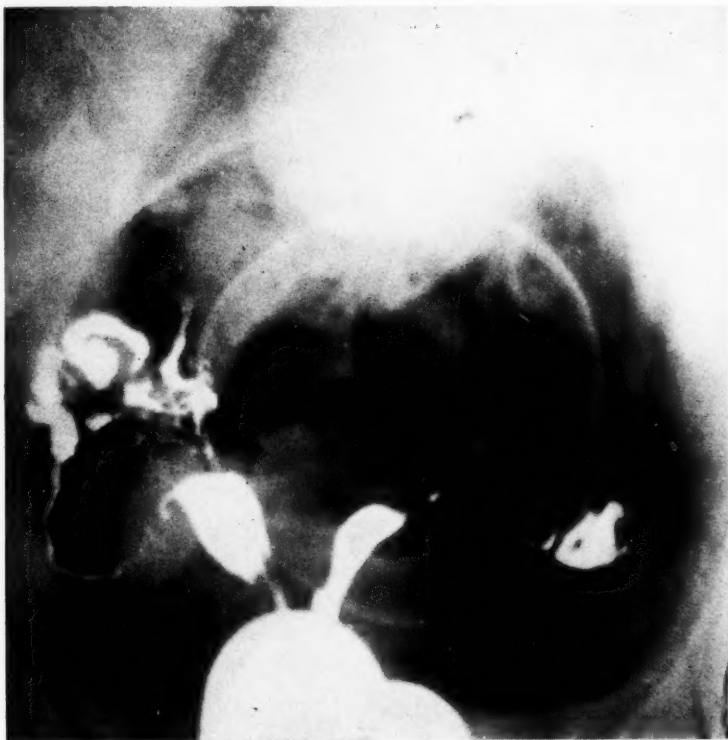
Fig. 2. Septate uterus. Large gas-inflated tubo-ovarian cyst. (Courtesy of Dr. C. C. Doherty.)

pearance. We reasoned that if this fluid was inside the cystic mass, and contained the oil as well, then it was not likely to be an ovarian cyst, for the ovary has no portal of entry, unless there be a forced tubo-ovarian connection. However, tubo-ovarian swelling had to be considered. Further examination and study of the films revealed a shadow corresponding to the ovary beyond the cystic mass. Finally, it was necessary to admit a diagnosis of unilateral hydrosalpinx, and this in the complete absence of history or other findings of an inflammatory lesion.

being found. One year after operation the patient became pregnant and was delivered, in June, 1929, of a full term, normal child.

When the oil takes the form of globules it is reasonable to assume that it has entered a fluid medium. When any oily liquid is caused to enter a fluid medium, being projected through a fine lumen such as a Fallopian tube, the oily compound is formed into globules by virtue of its different viscosity and surface tension, and rises or sinks according to its specific gravity. These globules do not readily coalesce and, there-

fore, it is not uncommon to find them accumulated in "pearl clusters" in a fluid medium. To decide whether this medium is enclosed fluid, as in hydrosalpinx, or fluid encysted in peritoneal adhesions, or whether the uterus inflate a tubo-ovarian cyst through a tubo-ovarian fistula. This case (Fig. 2) was confirmed by operation. An interesting feature was that the surgeon failed to find the cyst, but removed the ad-

Fig. 3. Arcuate uterus. Bilateral cysts (right dermoid). Tubal sphincter visualized on left.

it is free intraperitoneal fluid, requires careful and studious interpretation. Without the additional use of pneumoperitoneum one can rarely be sure, and, even with the latter, a series of follow-up films over a period of twenty-four hours may be needed to decide the issue. We have seen this "pearl" formation in seven cases in hydrosalpinx. We have also seen the lipiodol divided into fine globules in free intraperitoneal fluid.

On the other hand, we have observed in one case gas which was introduced through nexa on the affected side. Subsequently the cyst was reinflated with gas through the uterine end of the tube and the tubo-ovarian origin of the cyst revealed. This was confirmed by the pathologist.

THE DIFFERENTIATION OF SMALL OVARIAN CYSTS FROM TUBAL AND TUBO-OVARIAN SWELLINGS

This group presents a very picturesque set of films. The tubes fill quite normally with iodized oil and may or may not show intra-

peritoneal spill, but previous examination will have shown small (3-6 cm. size) masses palpable on one or both sides. In the absence of pneumoperitoneum in this group, we have never found the films of diagnostic value except in a negative sense, *i.e.*, by eliminating tubal pathology.

On the other hand, by the combined method we have been able readily to diagnose unilateral and bilateral ovarian cysts, and to differentiate dermoids from simple cystomata. In several cases right dermoid and left simple cyst were shown on the film and found later at laparotomy. The accuracy and completeness with which the pelvic status appears on the roentgen film in these cases is truly remarkable. One instance of this is illustrated below.

Mrs. S. D., aged 24, had been married two years and was in her first pregnancy. The uterus appeared about the size of a three and one-half months gestation. On November 19, 1927, she spontaneously aborted a small fetus and placenta, the latter showing the typical picture of early hydatid mole formation. The post-natal examination disclosed a uterus of normal size, with the right ovary definitely cystic. It was thought to be the theca lutein cyst so commonly found (usually bilateral) with hydatid degeneration, and the patient was advised that it would probably disappear spontaneously.

Because of the persistence of the cyst, a transabdominal pneumoperitoneum was induced June 7, 1928, and 5 c.c. of lipiodol instilled into the uterus. The films (see Fig. 3) disclosed bilateral cystic ovaries. The right ovary was larger than the left and contained a dense mass, suggesting dermoid cyst. The uterus was arcuate. Both Fallopian tubes contained lipiodol to the fimbriæ. At laparotomy (June 11, 1928) resections of a dermoid cyst from the right ovary and of lutein and follicular cysts from the left ovary were performed.

Tubo-ovarian masses are usually of in-flammatory origin, and the tubal closure is commonly found in the interstitial or isthmal portion of the tube. If so, no lipiodol will be found in the tubes, but the characteristic triangular shadow of the uterine cavity will be seen. If the mass is unilateral, one tube may show filling to the fimbriated end, or even may show spill, depending upon the degree of pelvic inflammatory damage which has occurred as the result of the infection. These results are not invariably present, however, but as we have previously shown (8), unilateral tubal filling may be due solely to unilateral cornual spasm. It is advisable, in all cases where the findings may be misinterpreted, to take films at intervals of a few hours, over a period of twenty-four hours.

In this brief report, we have made no attempt to analyze our complete series, as the average films present no great diagnostic difficulty. The viscera are usually so clearly visualized by the combined method that the gynecologist and roentgenologist have little difficulty in harmonizing their opinions. As a rule the gynecologist must rely to a great extent upon bimanual palpation, which often leaves him with indefinite information as to the exact nature of a pelvic mass which he may find. As illustrated above, even in the presence of unusual pelvic pathology, we have been able to visualize the viscera and thereby establish an accurate diagnosis. With our increased experience in the use of combined iodized oil and pneumoperitoneum in gynecology, we feel that we may recommend this method as a safe and precise means of pelvic diagnosis.

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THE MEASUREMENT OF THE INTENSITY OF THE GAMMA RAYS OF RADIUM IN r-UNITS

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AFTER the unit of the roentgen-ray intensity, "one r," was accepted by the International Congress of Radiology, it was desirable to determine, again, whether this unit might also be used to measure the intensities of gamma rays of radium. The first attempt to measure intensities of both roentgen and radium radiation in terms of the same unit was made by Friedrich and Opitz (1), who employed the "electrostatic" unit. This investigation was unsuccessful for two reasons: (1) The gamma-ray intensities were not measured in e-units directly, but were calculated indirectly by a comparison of the erythema skin reactions produced by both types of radiation with those produced by the roentgen-ray intensities which had been measured in e-units; (2) The Friedrich "e-unit" in use at that time was not the present international r-unit.

In 1924, Glasser (2), using a modified e-unit, made a comparison of radium and roentgen-ray intensities. He found, by direct measurement, that 1 mg. el hr. = 1.69 e-units (or r-units) when using a radium pack of 4 cm. diameter and a filter of ¼ mm. lead plus 1 mm. brass at a distance of 2 cm. from the center of the radium capsule to the center of the ionization chamber. We now find that this value, obtained six years ago, agrees satisfactorily with the results obtained in our recent experiments, which were carried out with improved apparatus. This proves that the modified e-unit which was used at that time is practically identical with the r-unit of to-day. The results of our investigation are presented in this discussion.

In 1925 Lahm (3) discussed this problem. His results, however, were not quite accurate, particularly because he also made an indirect calculation of the r intensities by comparison of the erythema reaction of radium with that produced by roentgen rays. It will be shown in this paper that this indirect method of estimating gamma-ray intensities in r-units may lead to considerable error. From his experiments, Lahm drew the conclusion that 450 mg. el hr. = 600 r = 1 skin-unit dose with a radium preparation 1.5 cm. in length, filtered by 1 mm. of brass, at a distance of 1 centimeter. In other words, 1 mg. el hr. = 1.34 r-units. This value was accepted by other investigators (Jona, 4, and Neeff, 5), and recently was again used by Lahm (6), but it does not agree with our results.

Kessler and Sluys (7) have tried to make an absolute determination of the r-unit for gamma rays by employing a large air-ionization chamber constructed somewhat on the same general principles as that used for roentgen-ray measurements, though they have not published their results. Stahel (8) also made relative intensity measurements on gamma rays with a micro-ionization chamber; but his results are as yet unpublished. Recently Jona (9) presented some of the results of his investigations of the same problem. His values approximate those which we gave several years ago. Neeff (10), on the other hand, in a series of measurements on gamma-ray doses in r-units, arrives at conclusions which do not agree with our results.

With their condenser dosimeter which lends itself particularly well to this kind of
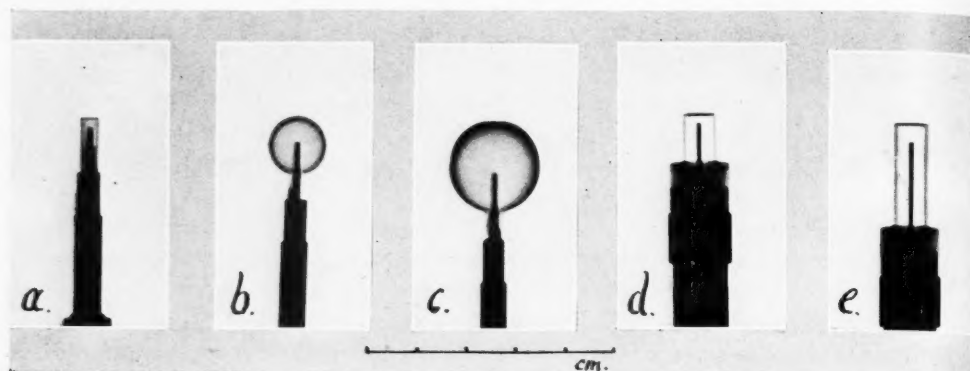
Fig. 1. Radiographs of the five chambers.

measurement, Glasser, Portmann, and Seitz (11) in 1927 took up the question of the measurement of the intensities of gamma rays in r-units. Their results, using different types of radium applicators, were published in several papers, and the r-values obtained were checked by the biological reactions. These experiments and this report are a continuation of this investigation.

In order to unify the problems of radium dosage, detailed descriptions of the measuring apparatus used in different laboratories are desirable. Therefore, we shall give a short description of our apparatus and procedure, together with the results we obtained in the measurement of gamma-ray intensities in r-units. The introduction of the r-unit into radium therapy is desirable because it may not only replace the other physical and biological dose units which are in use at the present time, but it also permits the direct comparison of r-doses in roentgen and radium therapy. Two questions, then, are of practical interest: (1) Can the r-unit be used to measure the intensity in radium therapy? (2) What is the relation between the biological effects of identical r-doses in roentgen and radium therapy? According to our results, we may answer that, under certain experimental conditions, the r-unit is a satisfactory measure of the intensities of the gamma rays of radium. A comparison of r-doses in roentgen and radium therapy shows that under certain conditions of radiation the number of r-units required to produce identical reactions on the human skin varies within wide limits. Under given technical conditions, 2,000 r-units with the gamma rays of radium produce the same erythema reaction as 600 r-units with roentgen rays.

MEASURING APPARATUS

In determining the intensities of gamma rays in r-units we employed the condenser dosimeter, previously described in detail (11). This instrument, which was built under the direction of V. B. Seitz, consists of a string electrometer and a condenser with ionization chamber attached. The condenser unit is first connected with the electrometer, and both are charged to a certain known potential, as indicated on the calibrated scale of the electrometer. The condenser unit is then removed from the electrometer, and the ionization chamber is exposed under given conditions to the gamma rays. After exposure of the chamber for a definite time, the condenser unit is again connected to the electrometer, and its loss of charge is read on the calibrated scale.

This loss of charge can be directly transformed into the intensity in r-units which acted upon the ionization chamber if the electric data of the total instrument (the volume and material of the ionization chamber and the time of exposure) are known. Undesirable effects which may be produced upon the condenser unit by the radiation, as well as effects upon the dielectric, have been minimized in this instrument, and may be controlled continuously by replacing the ionization chamber with a small amber cap and again exposing the condenser unit to the direct radiation. Even the penetrating gamma rays cause no loss of charge or other change than can be observed during the time ordinarily employed in making the measurements. Thus the objection against the instrument which recently was raised by Gueben (12) is nullified.

Gueben maintains that the conductivity of the dielectrica used in the instrument offers sources of considerable error. His statement that care must be used when certain types of dielectrica are exposed to penetrating radiation is correct; and we called attention to the possibility of changes in the conductivity of such dielectrica in an earlier publication (11). These errors are avoided by special selection of the dielectrica used and by the design of our instrument.

The ionization chambers employed in our experiments have also been previously described (11). They are of the air-wall type, and vary in volume from 1/35 to 2 cubic centimeters. Radiographs of the five chambers are shown in Figure 1. (These radiographs were made with Grenz rays of 10 K.V.) The small cylindrical chamber "a," of 1/35 c.c. volume, was used for making the measurements when in close proximity to the radium preparations. It is necessary to use such a small chamber for distances of less than 1 centimeter. For greater distances, the sphere chamber "b," of $\frac{1}{2}$ c.c. volume, is preferable and can be recommended for almost all measurements of intensity when the distance is over 1 centimeter. In order to study some points of special interest measurements were also made with the sphere chamber we previously recommended, which has a volume of 2 c.c., and also with two cylindrical chambers the volumes of which are, respectively, $\frac{1}{4}$ and $\frac{1}{2}$ cubic centimeter. We shall show later that there is some variation in the measurements of intensity made with these different chambers for distances up to $1\frac{1}{2}$ centimeters. At distances greater than $1\frac{1}{2}$ cm., however, the intensities are practically independent of the type of the ionization chambers investigated.

The determination of intensities of gamma rays in r-units by means of calibrated small ionization chambers is an indirect method. The direct method of determining intensities of gamma rays in r-units with a large air-ionization chamber, as done by Stahel, for instance, is difficult. We preferred the indirect method after we had previously (11) shown that there is a difference of only 5 per cent between ionization currents produced in a 1 c.c. graphite chamber and a 1 c.c. magnesium chamber when using radium rays filtered with 2 mm. of brass, or an equivalent thickness of other metals. In the well-known dosage formula

$$I = \frac{C \times (V_2 - V_1) \times p}{300 \times vol. \times t} \ r/sec$$

the factor "p" is 1 when using any ionization chamber made of a material with an effective atomic number equivalent to approximately that of air, that is, 7.69. There is a possibility that hard gamma rays of radium produce certain unknown ionization effects which might be the source of errors in our indirect method of measuring the r-unit for gamma rays. According to our present information, however, our indirect method seems to lead to accurate intensity values of gamma rays in r-units.

The radium preparations used in our experiments were radium bromide and radium emanation, and they were of different sizes. Usually we employed preparations of 1.2 and 2 cm. length with a ½ mm. platinum or 2 mm. brass filter. Radium tubes with a 1.2 mm. brass filter were also used occasionally. According to our measurements, the differences between intensities of radium filtered with 2 mm. or 1.2 mm. of brass are slight. In order to determine the intensities measured with preparations filtered with brass and those filtered with ½ mm. of platinum, 2 mm. of lead, and ¼ mm. of steel, we measured the intensities for these different filters and collected the results in Table I, using a distance of 2 cm. from the center of the radium preparation to the center of the ionization chamber.

It will be seen from these data that the variation of the intensities of radium filtered with the 2 mm. brass filter or 1.2 mm. brass filter and the ½ mm. platinum filter are not great. The following measurements, which were usually made with the ½ mm. platinum filter, therefore, can easily be applied to preparations with a 2 mm. or 1.2 mm. brass filter if a small correction is made.

TABLE I

RADIUM CAPSULE 2 CM. LONG; 2 CM. DISTANCE FROM RADIUM TO IONIZATION CHAMBER (C)

Filter	Intensity in r/mg. el hr.	Relative Intensity
2.0 mm. brass	2.00	100
1.2 " brass	2.07	104
0.5 " platinum	1.94	97
2.0 " lead	1.58	79
0.25 " steel	8.8	440

One of the greatest difficulties in measuring the r-intensities of radium was found to be in the correct adjustment of the distance from radium preparation to ionization chamber or to skin. In all of our experiments this distance was taken from the center of the radium preparation to the center of the ionization chamber. In order that the condenser unit with the small ionization chamber would always be in the same relative position, we constructed a rigid holder with a stop, so that the distance between ionization chamber and radium preparation could be measured exactly by a vernier scale which has an accuracy of 1/20 millimeter.

The results which show the number of r

TABLE II

RADIUM CAPSULE 1.2 CM. LONG; ½ MM. PLATINUM FILTER; MEASUREMENTS MADE IN AIR

Distance in cm.	Measured Intensities in r/mg. el hr.			Calculated Intensities in r/mg. el hr.	
	Small Chamber (a)	Sphere Chamber (b)	Sphere Chamber (c)	$I = \dfrac{13.6}{d}$ tang -1 $\dfrac{0.6}{d^2}$	$I = \dfrac{8.0}{d^2}$
(0.15)	....	....	....	(120)	....
0.4	31.3	....	....	33.5	50.0
0.5	22.2	....	....	23.7	32.0
0.6	16.9	14.3	....	17.8	22.2
0.8	11.0	9.3	....	11.0	12.5
1.0	7.6	6.6	....	7.4	8.0
1.2	....	4.8	5.7	5.3	5.6
1.4	3.9	3.6	4.1	3.9	4.1
1.6	....	....	3.2	3.1	3.1
2.0	....	2.1	1.9	2.0	2.0
3.0	....	0.92	0.91	0.90	0.89
5.0	....	....	0.32	0.32	0.32
10.0	....	....	0.08	0.08	0.08

per mg. el hr. and the effect of varying the distance are collected in Table II for the small ionization chamber "a," the small sphere chamber "b," and the large sphere chamber "c." They were obtained with a

tained from the measurements made at greater distances.   In the last column are added the intensity values calculated by means of the law of inverse squares.   These latter values refer to a point source, while
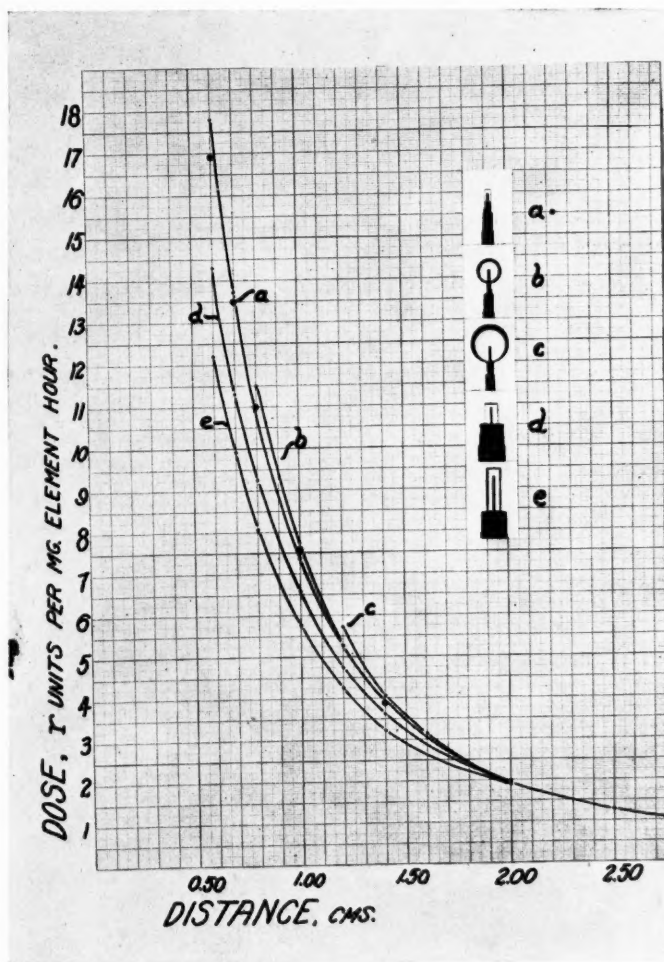
Fig. 2. Intensities measured with the various ionization chambers.

preparation of radium bromide, 1.2 cm. in length, 25 mg. el, and a ½ mm. platinum filter. The intensity values calculated by means of the formula

$$I = \frac{13.6 \, \text{tang} - 1}{d} \frac{0.6}{d^2}$$

are shown in the fifth column of the table. The constants in this formula have been ob-

the values in the fifth column take into consideration the length of the radium preparation. Of course, all of the radium intensities could be measured by means of the small ionization chamber, but at greater distances the ionization current in this chamber becomes small and the exposure time therewith too long. The larger chambers were

TABLE III

Distance in cm.	Measured Intensity in r/mg. el hr.	Skin-unit Dose in mg. el hr.	Skin-unit Dose in r
0.5	23.7	84.5	2000
1.0	7.4	270	2000
1.5	3.5	570	2000
2.0	2.0	1,000	2000
3.0	0.9	2,220	2000
4.0	0.5	4,000	2000
5.0	0.3	6,660	2000
7.5	0.14	14,300	2000
10.0	0.08	25,000	2000

TABLE IV

Distance in cm.	Measured Intensities in r/mg. el hr.		Commercial Chamber 6 c.c.
	Cylindrical Chamber (d) ¼ c.c.	Chamber (e) ½ c.c.	
0.6	14.3	12.2	....
0.8	9.3	8.1	....
1.0	6.6	5.8	....
1.4	3.6	3.2	....
2.0	2.1	1.9	1.7
3.0	0.92	0.96	0.79
5.0	....	....	0.32
10.0	....	....	0.08

TABLE V
RADIUM PACK, 4 × 4 CM. AREA; 4 MM. BRASS FILTER

Distance in cm.	Measured Intensity in r/mg. el hr.	Skin-unit Dose in mg. el hr.	Skin-unit Dose in r
2.0	1.74	1150	2000
2.5	1.13	1770	2000
3.0	0.82	2440	2000
3.5	0.64	3130	2000
4.0	0.49	4100	2000
4.5	0.39	5150	2000

used to determine the minimum distance at which this type of chamber may be used to give accurate measurements of the intensities.

The results show that at distances greater than 1½ cm. the intensities measured with various chambers are identical. For shorter distances, however, only those values can be used that were measured with the small chambers. It is interesting to note the great increase of intensity which occurs when the chamber is in close proximity to the radium preparation. For example, a change in distance of 1 mm. corresponds to a change in intensity of 30 per cent. It is necessary, therefore, to measure distances very accurately in order to observe small changes of intensity.

The data of special importance for practical use in therapy are collected in Table II, which also shows the values for skin-unit doses produced with the various radium applicators. We have selected figures to represent the skin-unit dose which are most accurate according to our present knowledge and experience. Attention has often been called to the fact that there is great variation in the reaction to the different skin-

unit doses of radium which have been pro-
posed. The skin-unit doses reported by
different authors, for instance, vary between
200 and 700 mg. el hr., with preparations fil-
tered with approximately 1.5 mm. of brass
at a distance of 2 centimeters. Within a
certain limit the strength of the radium used
in biological experiments plays a definite
rôle, and we have, therefore, used prepara-
tions of about 100 mg. el hr. in our experi-
ments. We found that the skin-unit doses
which were cited in earlier publications and
which were taken from Quimby's values (13)
are somewhat too low. We increased these
doses, therefore, and arrived at the data
presented in the third column of Table III.
If these values are multiplied by the r doses
for the corresponding distance, the skin-
unit doses are obtained in r-units. Since
the values were found to be the same within
a few per cent, we averaged the observed
skin-unit doses and obtained the value 2,000
r for the observed skin-unit doses.

These values, which were obtained with
a radium preparation of 1.2 cm. length and
a ½ mm. platinum filter, can also be used
for the 2 cm. preparation with the 1.5 mm.
brass filter, with the exception of the inten-
sity at short distances. The same values may
be used in radium therapy for intracor-
poreal radiation, since the effects of scatter-
ing are practically all counteracted by ab-
sorption. The values collected in Table III
were measured in air without back-scatter-
ing. At the present time we cannot present
accurate data on back-scattering, but we be-
lieve it is probably between 5 and 10 per
cent of the direct radiation.

In comparing the results obtained with
the number of r-units per erythema dose for
roentgen rays, it is found that the number
of r-units per erythema dose for the gamma
rays of radium is much higher than that of
hard roentgen rays, provided that our indi-
rect determination of the r-intensities for
gamma rays of radium is accurate. We are

now collecting more information on this
question by testing these doses of radiation
on *Drosophila* eggs, and expect to present
a discussion of the physical-intensity values
and their biological reaction in the near fu-
ture.

In order that the physical data may be
complete, we wish to add some results which
were obtained when measuring with other
types of ionization chambers. Two cylin-
drical chambers of ¼ c.c. and ½ c.c. and a
commercial ionization chamber of 6 c.c.
were used. The results are presented in
Table IV. They have been obtained under
the same conditions as those given in Table
II.

By comparing the intensities which were
obtained with these chambers with those
shown in Table II, it may be seen that all
ionization chambers, with the exception of
the 6 c.c. chamber, gave the same intensities
at distances greater than 2 centimeters.
The large commercial chamber, however,
does not accurately indicate the intensities
for distances less than 5 centimeters. All
the intensities which were measured with
the various ionization chambers are graphi-
cally shown in Figure 2. The different
chambers and the intensity curves deter-
mined with them are designated in the same
manner as the data given in Figure 1.

We have also included the intensity
measurements made with a radium pack of
4×4 cm., using a brass filter of 4 mm.
thickness. The intensities of this group at
various distances are collected in Table V.
This radium pack acts as a point source for
distances greater than 4½ cm., beyond
which the values of Table II may be used.
The results in the third and fourth columns
have also been obtained by the same pro-
cedures as the values of the corresponding
columns in Table III.

CONCLUSIONS

With certain precautions and under cer-
tain conditions the r-unit can be satisfac-

torily employed to measure the intensity of the gamma rays of radium. With the gamma rays of radium 2,000 r-units will produce a reaction on the human skin which is usually designated as a skin-unit dose.

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DIAGNOSTIC EXPOSURES IN r-UNITS[1]

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UNDER ordinary circumstances and during uncomplicated examinations the amount of radiation falling on the skin of the patient does not reach clinical importance. This fact is supported by the thousands of examinations which are conducted with a relatively insignificant number of accidents. There are, however, certain circumstances which demand a rather accurate knowledge of the total energy applied.

Difficult or frequently repeated examinations, particularly in obese patients, serial radiography, cinematographic radiography, and examinations performed on patients who are receiving or have received X-ray therapy, all introduce the danger of overexposure.

Erskine (2) as early as 1922 determined the erythema time with diagnostic rays at 10-inch distance and found that at 60 K.V. the minimum E.D. corresponded to 400 ma.-sec. of unfiltered, or 800 ma.-sec. with 1 Al filter. A year later Witherbee and Remer (1), applying their arithmetical method of dosage calculation to the various U. S. Army Manual exposure settings, tabulated the number of plates which might safely be taken.

In 1926 Frik (4) made what appears to be the first move in evaluating radiographic exposures in physical units. He measured the amount of radiation used in fluoroscopy and radiography of both the chest and the gastro-intestinal tract. As a result of his experiments he advocated using greater filtration in gastro-intestinal fluoroscopy and showed that by this procedure the amount of radiation striking the skin during a given fluoroscopic examination might be reduced to one-half or one-third the amount normally used. This reduction in skin dosage was accomplished without impairing the contrast in the fluoroscopic image.

This work of Frik seems to have been the starting point for several articles which appeared in succeeding years, dealing with this subject.

Pohle (3) measured the output of diagnostic machines at 75 and 100 K.V. with 5 ma. and then determined the erythema time of this quality of radiation. He calculated that in gastric examinations with fluoroscopy and the maximum number of films the posterior surface of the body received 60 per cent E.D.

Chantraine and Profitlich (5) studied the output of radiographic and fluoroscopic machines operated at the lower kilovoltages, and derived tables showing the actual amount of radiation received by the skin. They corrected the wave length dependence of their Siemens chamber against a Veifa electroscope. This correction, in addition to the fact that they used soft beams of radiation, accounts for the difference between their results and those obtained by Frik.

Saupe (6), using the Küstner method of measuring, tabulated the average r delivered in certain exposures and calculated 100 r as the safe limit in radiography.

Braun, Hase, and Küstner (7) made still further measurements upon diagnostic beams, and compiled tables of the output of their machines for 1 ma. and voltages ranging from 30 to 100 K.V.P. They further calculated the actual energy required to make various exposures.

In view of the need for readily available data relative to the amount of radiation re-

quired to make radiograms and the paucity of such data in the English literature, it was decided to measure the output of the available machines and formulate exposure tables.

Six different machines were calibrated over their commonly used range. Four of these were mechanically rectified; in two, rectification was performed by the Coolidge tube. In all cases the measurements were made with the actual milliamperage used in the technic.

A Siemens-Halske dosimeter, using a Glocker chamber and calibrated against a Küstner instrument over the quality region used in radiography, was used to measure the output of the machines. The advantages

of short readings and constant uranium control were the principal reasons for using this instrument. The dosimeter was re-checked against the Küstner several times during the course of the experiment and was found constant within the limits of experimental error. Each series of measurements on the radiographic machines were repeated at least twice.

Due to the high intensity produced by some of the technics, measurements were carried out at different distances and corrected to a common distance according to the inverse square law. The error introduced by disregard of air filtration is negligible at the shorter distances and does not amount to more than 5 or 10 per cent at
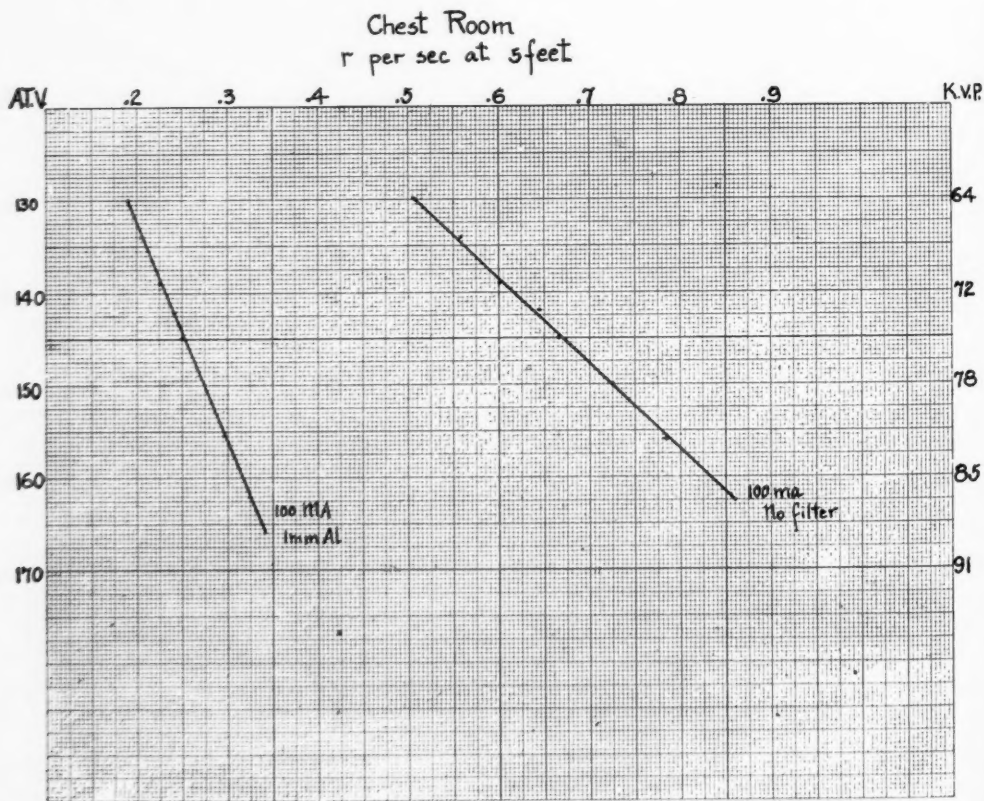

Fig. 1. Typical output chart for a diagnostic machine.

TABLE NO. I-A

EXTREMITY GROUP

Part radiated	Target-to-film distance	r–units at 12 inches F.S.D. Plain films	Screens	Quality range
Fingers	30 inches	½–1	–	50–65 K.V.P.
Hand	"	1–3	1/8–1/2	"
Wrist	"	1–5	1/4–1/2	55–70 K.V.P.
Forearm	"	2–6	–	"
Elbow	"	2–7	1/2–2	"
Humerus	"	2–8	–	"
Shoulder	"	7–12	2–4	"
Foot	"	2–3	–	"
Ankle	"	2–5	1/2–1	60–85 K.V.P.
Leg	"	3–7	–	"
Knee	"	5–9	2–4	"
Femur	30 inches	Plain films 6–12 r		65–80 K.V.P.
Femur	30 inches	Screens and grid 3–10		70–90 K.V.P.
Humerus	30 inches	Screens and grid 1–4		65–90 K.V.P.
Shoulder	30 inches	Screens and grid 2–6		"

All exposures are calculated for one millimeter of aluminum filter unless otherwise indicated.

TABLE NO. I-B

HEAD GROUP

Part radiated	Target-to-film distance	r–units at 12 inches F.S.D. Screens	Screens and grid	Quality range
Jaw	25 inches	1/2–2 (with plain films 4–6)		75–85 K.V.P.
Skull:				
Lateral	25 inches	–	5.6–6.5	80–95 K.V.P.
A. P.	25 inches	–	7–12	"
Mastoid	Cone	3–5	–	"
Sinuses:	Contact cone F.S.D. to scalp			
Lat. frontal	14 inches	1–3	2–4	85–100 K.V.P.
Granger	14 inches	3–5	8–10	"
Caldwell	14 inches	3–5	9–12	"
Waters	14 inches	5–8	9–12	"
Vertico-mental	14 inches	7–9.5	12–14	"
Lateral sella	14 inches	3–5	–	"

longer distances for the softest radiation used.[2]

Graphs were then prepared for each of the machines, showing the energy output of the technics in common use on the particular machine in question. Figure 1 shows two such graphs. It may be seen that with fixed milliamperage, the output is practically a linear function of the voltage as long as the same Coolidge tube is used. From these

charts the energy output in any of the technics used may be calculated.

The minimum and maximum amounts of radiation delivered in making films of various parts of the body are presented in No. 1. These extremes range from the lightest to the heaviest specific part encountered. It will be noticed that the intensities are recorded at one of two distances, 12 or 60 inches F.S.D., and must therefore be corrected by both distance and back-scattering factors before the actual amount on the patient is known. In applying the first correction the target-to-skin distance must, of course, be known or estimated.

The second correction is calculated pre-

[2]The air filtration values for monochromatic radiation, as tabulated by Odencrants (8), are not strictly applicable to a heterogeneous beam. However, by determining the absorption in one or two millimeters of aluminum we may place a value on the softer, and hence more readily air-absorbed, portion of the beam. The diagnostic range measured in this manner gives an effective wave length of around 0.5 A.U. with one millimeter of Al, and 0.45 with two millimeters of Al. The half value layer in Al ranges from one to one and one-half millimeters, when a filter is used in the tube stand, and between one-half and one millimeter when no filter is used.

TABLE NO. I-C
THORAX GROUP

Part radiated	Target-to-film distance	r–units at 12 inches	Quality range
Ribs	30 inches	Screens and grid 1–4.5	65–85 K.V.P.
Chest	40 inches	Screens 1/4–2/3	60–80 K.V.P.
		r–units at 5 feet Screens	
Chests P. A.	7 feet	0.08–0.4	60–85 K.V.P.
Lateral	10 feet	1/2–3	65–90 K.V.P.

TABLE NO. I-D
ABDOMEN

Part radiated	Target-to-film distance	r–units at 12 inches Screens	Screens and grid	Quality range
Gall bladders	Contact cone 18" F.S.D.		2–11	60–80 K.V.P.
Gastric (Opaque Meal)	30 inches	3–10		90–110 K.V.P.
Enemata (Barium)	36 inches	3–10		70–95 K.V.P.
Kidneys	30 inches		5–18	60–85 K.V.P.

SPINE AND PELVIS

Part radiated	Target-to-film distance	r–units at 12 inches Screens	Screens and grid	Quality range
Cervical spine:				
A. P.	30 inches		2.5–6	70–80 K.V.P.
Lateral	8 feet	½–1 r (at 5 ft.)		
Dorsal spine:				
A. P.	30 inches		3–20	75–95 K.V.P.
Lateral	30 "		6–32	80–100 K.V.P.
Lumbar spine:				
A. P.	30 inches		5–30	75–95 K.V.P.
Lateral	30 "		10–60	80–110 K.V.P.
Pelvis:				
A. P.	30 inches		2.5–16	75–95 K.V.P.

cisely only with some difficulty. The many changing factors—quality, field size, and part radiated—tend to introduce shifting errors of a magnitude which renders any attempt at more than an approximation illusory.

Based on water phantom measurements we estimated the amount of back-scattering in diagnostic radiation to be between 15 and 25 per cent. Back-scattering correction may be avoided entirely by regarding it as practically constant throughout the diagnostic range. This simplifies the calculation and allows the estimation of the total amount of energy administered in terms of percentage of the "air value."[3] (9) With Table I and a knowledge of the target-to-skin dis-

[3]As will be seen later, under the discussion of quality and film latitude effects, the influence of back-scattering on the total amount received by the skin becomes insignificant by comparison.

tance the amount of energy in terms of "air value" which falls upon the skin may be calculated.

This brings us to a subject of vital importance to radiologists, namely, the amount of radiation which may safely be used in diagnostic exposures.

Frik (4) based his limit exposure determination on 700 r (air).

Saupe (6) and Braun, Hase, and Küstner (7) believe 100 r the upper limit of safety, while Chantraine and Profitlich (5) use 300 r as the basis for some of their fluoroscopic calculations.

Our experience leads us to endorse the limit set by Saupe, namely, 100 r. One hundred fifty r (measured in air) of the quality commonly used in diagnosis will produce pigmentation in an appreciable number of

cases, while an approach to 300 r begins to enter the epilating range. Very occasionally we see pigmentation following the administration of 100 r.

The safe limit in diagnosis, then, would appear to be about one-third of the "toleration dose," or 100 r, and while the range between 100 and 200 r is fairly safe, it should be entered only when necessity demands.

It is important to bear in mind that three major factors aside from biologic differences cause variations in the amount of radiation falling on the skin in making radiograms: the quality of the radiation, the latitude of the film, and the nature of the equipment in use.

The softer beams of radiation, used to increase contrast, require much larger amounts of energy incident on the skin to produce radiograms than do the more penetrating beams. It becomes apparent from this that the safest beam for any particular part is that which gives the greatest penetration compatible with satisfactory contrast.

As will be seen in Table I, we have expressed quality in terms of kilovolts (measured with a sphere gap). We realize that, strictly speaking, this method is somewhat inaccurate. The wall thickness of the tube, the thickness of the protective filter, as well as the type of rectification, all introduce variations in quality which a sphere gap measurement would not detect. On the other hand, sphere gap measurements have in the main been entirely satisfactory for transferring radiographic technic. It is for this reason that gap measurements are used to express quality.

The second factor introducing major variations in the amount of radiation used in taking radiograms is film latitude. This varies somewhat depending on the density of the part to be demonstrated and on whether screens are or are not used. How-

TABLE II

Part radiated		Amount on skin (r)	Number of films totalling 100 r
Hand		0.5	200
Forearm		1.2	80
Elbow		1.3	75
Humerus		1.7	60
Shoulder		3	30
		1.8*	55
Knee		2.5	40
		1.5*	65
Femur		4.0*	25
Chests	A. P.	0.3†	330
	Lat.	0.8†	120
Jaw		2.5	40
		0.8†	120
Skull	Lat.	4.5*	20
	A. P.	12*	9
Sinuses:			
Lat. Frontal		2.5†	40
Granger		4.5†	22
Caldwell		4.5†	22
Waters		7†	14
Vertico-mental		9.5†	10
Cervical spine		2.5*	40

*With screens and grid.
†With screens.

ever, it usually amounts to 50 per cent or more on either side of the average. This means that films of diagnostic value may be made with 50 or 150 per cent of the optimum 100 per cent energy for that part. In many instances the variation is even greater.

Examples of this wide latitude may be seen particularly in the radiography of small parts on plain films. Satisfactory radiograms of the hand may be made over a variation range of 300 per cent.

The third factor influencing the radiographic energy requirements has to deal with the efficiency of screens and grids, as well as the filtering action exercised by various interposed pieces of equipment, such as table tops. It will be seen from a consideration of these factors that the safest table to use as a limit in any laboratory is one which represents the highest values met in that laboratory. This thought has been followed in preparing Table II, and 100 r is used as the safety limit in figuring the number of films allowable.

In Table III an attempt has been made to demonstrate the manner in which radia-

TABLE III

(1 MM. AL FILTER THROUGHOUT)

Part	Thickness in centimeters	K.V.P.	ma.	Target-to-film distance cm.	Time (secs.)	r per exposure calculated on skin	No. of films totalling 100 r
Dorsal spine A. P.*	15	76	20	75	4½	1.4	70
	17	80	20	75	5½	2.1	46
	20	84	20	75	7½	3.6	28
	24	87	20	75	10½	7.2	14
	28	92	20	75	12	9	10
Lateral*	18	78	20	75	5½	2.	50
	20	80	20	75	5½	2.5	40
	24	84	20	75	8	4.7	20
	30	90	20	75	11	10	10
	34	99	20	75	18	22	4
Pelvis*	15	78	20	75	3½	1.5	65
	20	82	20	75	7¾	4.	25
	25	86	20	75	10½	8.	12
Lateral lumbar*	23	85	20	75	10	7.7	13
	26	92	20	75	13½	10.5	9
	30	100	20	75	19½	21.5	4
	36	100	20	75	28	47.	2
Gastric region†	16	95	60	80	½	1.4	70
	20	98	60	80	½	2.2	45
	24	100	60	80	½	2.6	38
	30	105	60	80	½	4.	25

*With screens and grid.
†With screens.

tion requirements change with increasing thickness of the part.

It must be understood that the values in all of these tables hold exactly only with the technic for which they were compiled. Our required radiation values agree within expected limits with those published by the previously mentioned German workers. On the other hand, the amounts of radiation administered in other laboratories might reasonably be expected to vary as much as 100 per cent from the values presented here. Those workers using lower voltage, blacker films, or less efficient accessories might exceed these values, and, consequently, have a lower limit of safety.

Those radiologists adhering to a fairly penetrating technic and using efficient equipment will find that these values are somewhat high. This is particularly so when our higher values, designed for heavy patients, are applied to patients of average size. An example of this fact may be seen in a consideration of the radiation require-

ments in chest radiography. With double screens and good penetration, satisfactory films are obtained in the average patient with 1/12 to 1/10 r incident on the skin.

It becomes evident that those roentgenologists using or planning to use multiple exposure technics should depend on the individual calibration of their machines and measurements of their patients.

The addition of fluoroscopic to radiographic examinations naturally decreases the number of films which may safely be taken. The output from fluoroscopic sets varies quite a bit, and calculation of safety limits on the basis of milliampere-minutes is not without risk. Indeed, it is far safer to actually test the erythema time on small skin areas, if calibration is not available.

Chest fluoroscopy at the University Hospital is performed with an intensity of between 10 and 15 r per minute, whereas gastro-intestinal work may require up to 20 r per minute incident on the skin.

SUMMARY

Six diagnostic X-ray machines were calibrated over their commonly used range. Calibration charts were prepared which enabled the accurate calculation of the amount of energy used in diagnostic exposures.

From these charts and exposure tables based on thousands of satisfactory radiograms, the largest and smallest amounts of radiation used for certain parts were determined.

Safety tables based on the energy required for the heaviest part likely to be met with were prepared. Further tables were prepared illustrating the increase in energy with increasing thickness of the part.

The influences of quality of radiation, type of equipment, and film latitude on the total radiation applied are noted and the advisability of using the greatest penetration compatible with adequate contrast stressed.

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DISCUSSION

DR. ARTHUR W. ERSKINE (Cedar Rapids, Iowa): The striking point brought out by the essayist in this presentation is that, with proper radiographic technic, the quantity of X-rays as measured on the skin in absolute units is surprisingly small, and consequently a large number of films can be made in safety. Dr. Pohle, at the University of Wisconsin, independently from this work, made some investigations, and he has allowed me to present a slide which gives the average results of some of his measurements. The last column shows the average number of r-units on the skin and they agree rather well with the observation of Barnes and Meltzer. For instance, Dr. Pohle observed that the skin received 6.4 r for an average antero-posterior skull, while the essayists report, with various technics, a range of from 3 to 9.5 r; so we can say that the two observers agree within 50 per cent, at least.

It must not be assumed that the number of films as shown in the tables mentioned by the essayists can be safely made with a poor technic or with an uncalibrated technic. We know, of course, that with poor technic the exposures are sometimes many times larger than necessary. I would suggest, as the essayists did, that those who routinely make many films of single patients, and especially those who make cinematographic exposures, should have their diagnostic apparatus calibrated.

DR. BARNES (closing): I wish to thank Dr. Erskine for his discussion of the paper. One might bring out the possibility of taking a leaf from the book of Fricke, who introduced greater filtration in fluoroscopy of the gastro-intestinal tract. With 100 K.V. peak, a moderately large field and one millimeter of aluminum filter, phantom measurements will show that about four and a half or five centimeters of water will absorb 50 per cent of the energy striking the surface. That would mean, then, that we are putting on the skin, during exposures of heavy parts, radiation which does not get

through and affect the photographic film. It would seem that increasing filtration, particularly in radiography of heavy parts, might be worth while.

Can Radiology be a Science? A. E. Barclay. Brit. Jour. Radiol., November, 1929, II, 509.

This paper, presented before the Society of Radiographers of England, emphasizes the need of always looking upon the practice of medicine, including the practice of radiology, as an art rather than as a pure science, since one must always consider the patient's complex or psychology in evaluating not only the symptoms complained of but the signs elicited during the roentgenologic study. A brief outline of the progress of radiology since its inception and the days of the first gas tubes, when an X-ray tube was a "glass globe surrounded by a zone of profanity," is given, but while its development as a science has gone far, the patient's individual peculiarities, susceptibilities, and idiosyncrasies will always make the final evaluation of the radiologic findings something of an art. The paper closes with an apt quotation from Dr. Oliver Wendell Holmes: "Science is a first-rate piece of furniture for a man's upper chamber, if he has common sense on the ground floor."

J. E. HABBE, M.D.

THE QUARTZ MERCURY ARC[1]

By WILLIAM T. ANDERSON, JR., PH.D., NEWARK, NEW JERSEY

WHEN two carbons are attached to an electrical supply of 100 volts direct current and are made to approach each other, nothing happens until the distance between them is less than that of a very thin sheet of paper. Ordinary air is a very excellent non-conductor.

If the carbons be touched together, the current begins to flow and an enormous amount of heat and a temperature of approximately 3,500° C. is generated at the point of contact, for it is at this point that most of the resistance of the circuit is located. If the carbons are now separated slightly, *e.g.*, half an inch, and if the air between the carbons were in the same condition as before, the flow of current would cease immediately; but the air between the carbons is not in the same condition. The entire region is filled with ionized gases and has now become a good conductor. The reason for the changed condition lies in the property of white-hot bodies to give off positive and negative ions and electrons in huge quantities. These ions carry the electric current. The negatively charged electrons given off at the cathode (negative electrode) bombard the anode, producing an intensely hot spot called the "crater."

Most of the light from the pure solid carbon arc comes from this positive crater, *i.e.*, it is pure temperature radiation produced as a result of the high temperature of the crater. The ionized vapors produce very little light, that which they do emit being largely confined to the so-called "cyanogen" band located in the long ultra-violet and violet portions of the spectrum. It is not surprising that the pure carbon arc emits practically no radiations corresponding to the short ultra-violet of sunlight, for the glowing carbons do not attain a sufficiently high temperature to emit the short wave lengths of radiation which the sun, at a temperature of 6,000° C., can produce.

Impregnation of the carbons with salts or metals produces the flame arc which is characterized by greatly increased light production in the ionized vapors and lowered temperatures, and therefore lowered light production, at the positive crater. Such an arc is vastly more efficient as a producer of light, for more of the energy is converted into light, and less into heat, than in the pure carbon arc. The kind of light emitted and the efficiency are dependent on the chemical nature of the impregnating materials.

It can be understood that as the electrode temperatures decrease, and more and more of the electrical energy is consumed in the ionized vapors, the efficiency and light production increase rapidly.

The electric arc reaches its peak of attainment in the vacuum quartz mercury arc. Here the electrodes are two pools of mercury maintained at a temperature between only 300 to 400° C., *i.e.*, comparatively cool. These give off some low temperature infra-red and heat, but no visible or ultra-violet light. The visible and ultra-violet radiations are all emitted by the ionized mercury vapor, a condition which permits attainment of the highest arc efficiency.

The natural efficiency of the quartz mercury arc in converting electrical energy into ultra-violet light is enhanced by a predominance of ultra-violet in the light emitted by ionized mercury. Considering the range of light wave lengths transmitted by the quartz, namely, from 1,850 Å.U. in the short ultra-violet to 40,000 Å.U. in the long infra-red, 28 per cent of the emitted energy
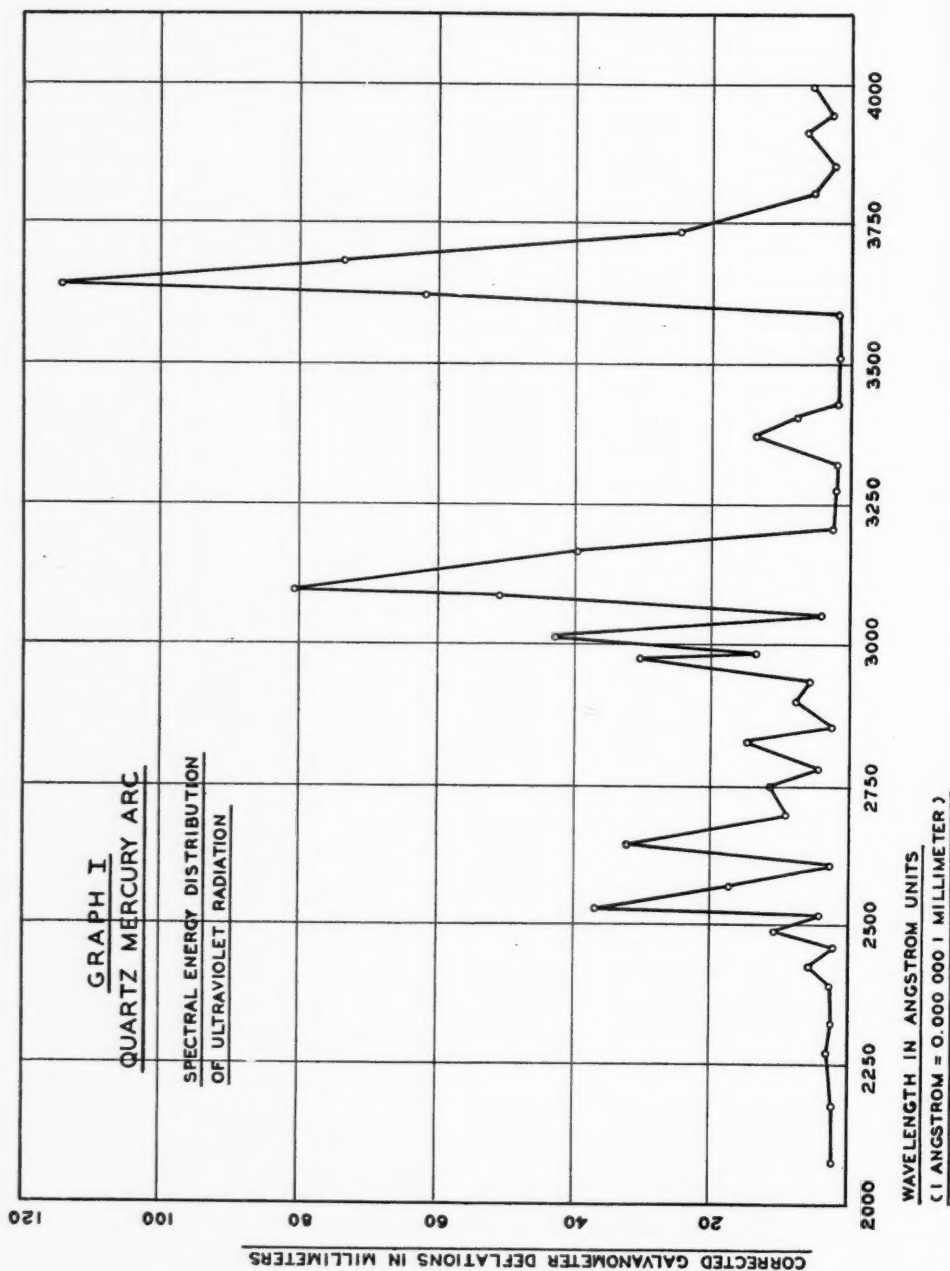
Graph I. Quartz mercury arc. Spectral energy distribution of ultra-violet radiation.

is in the ultra-violet, an amount greater than that obtainable by any other arc or light source.

The quartz mercury arc is not a cold source of light, deficient in infra-red rays: 52 per cent of its radiation is in the infrared, a proportion which compares favorably with that of the sun itself, which has 60 per

cent infra-red. It is only by comparison with the solid core non-impregnated carbon arc and the tungsten incandescent lamp, which produce 95 per cent of their radiation in the infra-red, that the conception of the quartz mercury arc as a cold source can be justified.

The quartz mercury arc is low in visible light as compared to the sun, the percentage ratio being about 20 to 33. The luminous efficiency of the quartz mercury arc is about 5 candle power per watt of input as compared to 3 candle power per watt for the impregnated flame carbon arc, and 1 candle power per watt for the solid core non-impregnated carbon arc. The quartz mercury arc is, therefore, a very efficient source of visible light.

It is important to consider not only the apportionment of energy between the different parts of the spectrum such as the ultra-violet, visible, and infra-red, but also the wave lengths available in each portion, *i.e.*, the spectrum, and the quantity present at each wave length.

All the arcs, including the quartz mercury arc, produce a continuous spectrum, *i.e.*, the light from them consists of every wave length from the very short ultra-violet to the long infra-red. However, not all wave lengths have equal amounts of energy: some wave lengths may possess many times the energy of their neighbors. Since the action of a wave length of light on a photographic plate is dependent largely on the intensity, a very short exposure records photographically only the more intense bands of wave lengths. Exposures of increasing duration record more and more of the wave lengths, until finally a time is attained when all wave lengths have affected the plate sufficiently to show the characteristic unbroken continuous spectrum.

In trained hands and with special precautions, a modification of the preceding may serve as a relative measure of the energy in various wave lengths of the spectrum. However, the ordinary spectrogram which is made without any regard to time of exposure and plate sensitivity indicates solely the wave lengths of light available and tells nothing of the light energy at each wave length. It is advisable not to judge a light source on its spectrum alone, for on this basis the ideal ultra-violet source would be the automobile spark plug operated on the automobile ignition system, which produces a better spectrogram than can be obtained by the quartz mercury arc or any of the carbon arcs.

The quantity of light energy available at each wave length is very important, and this the spectrograph ordinarily does not show. This must be determined by the physicist who either employs special photographic methods or by special apparatus separates the wave lengths and measures the energy in each. When this is done, it is found that the light from the quartz mercury arc comprises every wave length from the short ultra-violet to the long infra-red, *i.e.*, a continuous spectrum which has a low intensity and a number of groups of wave lengths, known as bands, which have exceedingly high intensity. The mercury arc is exceptionally rich in intense bands in that region of the ultra-violet spectrum corresponding to the short ultra-violet of sunlight. However, it must not be inferred from this statement that the energy distribution of the quartz mercury arc resembles that of sunlight. It does not. Neither does the carbon arc, nor any other light source dependent on ionization.

Because of the high efficiency and predominance of ultra-violet in its spectrum, the quartz mercury arc produces an intensity of ultra-violet radiation which can be equalled by other artificial light sources only by the expenditure of four or more times the electrical energy. With regard to power consumption, the quartz mercury arc
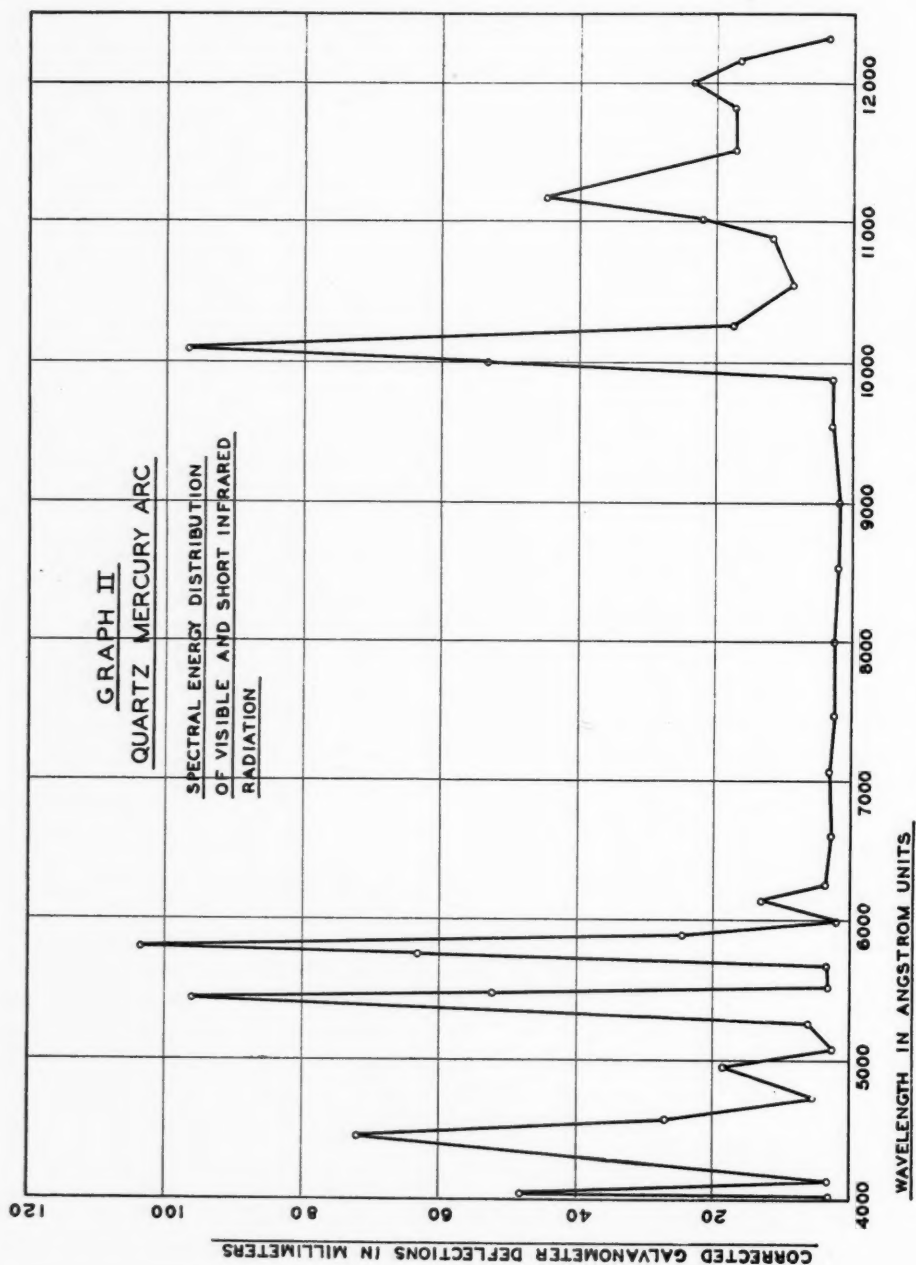
GRAPH II
QUARTZ MERCURY ARC

SPECTRAL ENERGY DISTRIBUTION
OF VISIBLE AND SHORT INFRARED
RADIATION

WAVELENGTH IN ANGSTROM UNITS

CORRECTED GALVANOMETER DEFLECTIONS IN MILLIMETERS

Graph II. Quartz mercury arc. Spectral energy distribution of visible and short infra-red radiation.

is the most economical artificial light source known.

In practice, the mercury arc must be enclosed in an evacuated envelope of quartz which can transmit the ultra-violet radiations and can withstand the temperature changes to which it must submit. Glass, even though it transmitted the ultra-violet, could not withstand the temperatures encountered in the arc tube. Thus fused

CORRECTED GALVANOMETER REFLECTIONS IN MILLIMETERS

WAVELENGTH IN MICRONS
(1 MICRON = 0.001 MILLIMETER = 10 000 ANGSTROM UNITS)

GRAPH III
QUARTZ MERCURY ARC

SPECTRAL ENERGY DISTRIBUTION
OF LONG INFRARED RADIATION
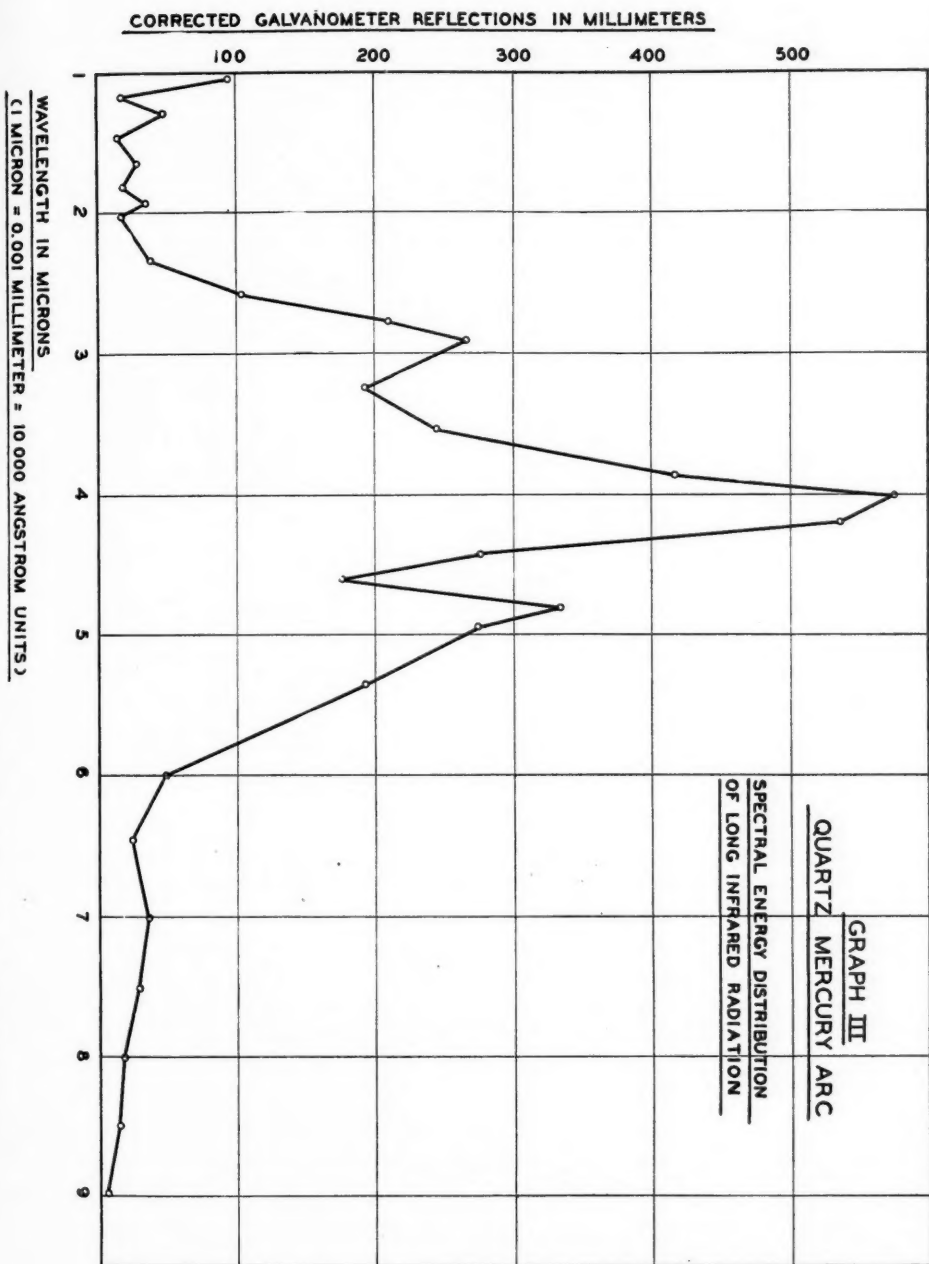
Graph III. Quartz mercury arc. Spectral energy distribution of long infra-red radiation.

quartz serves in a dual rôle, and is indispensable to the existence of the arc.

Quartz mercury arcs slowly deteriorate with use, though the deterioration does not affect the spectrum of the lamp. An old burner which has not been improperly cleaned and is not blackened because of a poor vacuum gives the same spectrum as a

new lamp. The decrease in the light produced is almost entirely due to changes in the quartz. The arc itself produces as much light as formerly, but the quartz envelope has decreased in transparency, and will not let as much of the light pass out. The resulting decrease in intensity affects both the short and long ultra-violet and the visible portions of the spectrum in a nearly equal measure.

The greatest rate of decrease in the intensity of a new lamp occurs during its first few hours of operation. Since all lamps are given several hours of operating tests in the laboratory prior to stocking and shipment, the initial drop in intensity has occurred prior to shipment. The subsequent decrease in intensity is very much slower. The Council on Physical Therapy of the American Medical Association have reported that "In the lamps investigated about ten years ago, the burners showed considerable blackening with usage. Since then marked improvements have been made in the construction of quartz mercury vapor lamps, which do not show the rapid discoloration with usage previously noted."

Deterioration may be hastened by outside causes, such as improper operation, handling, and cleansing. These factors may produce changes which affect greatly the spectral energy distribution, so that the relative intensity of various portions of the spectrum vary with age. It is especially important that only pure liquids which leave no residue on evaporation be employed in washing burners. Many a good burner has been completely ruined through failure to observe this precaution.

The properly aged quartz mercury arc lamp exceeds other light sources on like current consumption in the intensity of its ultra-violet radiation. Indeed, the great majority of the energy measurements which have been made and reported in the literature have employed partially aged quartz mercury arc lamps.

The hourly cost of owning and operating an alternating current quartz mercury arc lamp, which is the more expensive type, basing the computation on a life of 2,000 hours and including interest at 6 per cent on the investment, is 22 cents on the lamp and 8 cents for electric current, making a total of 30 cents per hour. No other lamp which gives even half the intensity can compete with the quartz mercury arc in price and operating cost. The quartz mercury arc is an economical light source.

The operation of the quartz mercury arc is extremely simple. With the exception of occasional washing of the burner, no adjustments of any kind are required. A large number of lamps have been in operation five years and more, without the burner having been once removed from its mounting. The quartz mercury arc is a convenient light source.

Since the arc is completely enclosed, there are no fumes or sparks. There is no excessive heat. Many quartz mercury arcs are operated unattended and overnight in chemical laboratories without any anxiety on the part of their owners, for there exists no fire risk. The quartz mercury arc is a carefree light source.

The widespread use of the quartz mercury arc lamp is evidence that the medical and scientific professions appreciate the advantages of the quartz mercury arc as briefly outlined. There is every reason to believe that as the properties of light become better known and understood, the quartz mercury arc lamp is destined to become one of the large factors in our civilization.

DECREASE IN EFFICIENCY OF GRENZ-RAY TUBES

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THE so-called Grenz or Bucky rays are X-rays of comparatively long wave length, and are found to be quite readily absorbed, even in materials of very low atomic weight, such as celluloid, air, and the tissues of the body.

The construction of cathode-ray tubes from which quantities of these soft rays

It is obvious that the deposition of any material of high atomic weight upon the window must reduce the quantity and alter the quality of the radiation escaping. The filament and the anode of the tube are both possible sources of such contamination. The filament operates at a high temperature. At every temperature there is a very definite
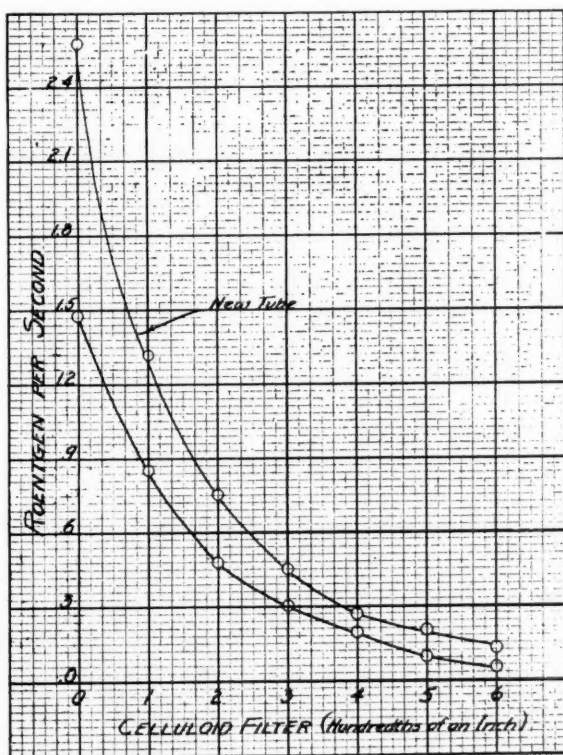

Fig. 1. Intensity measurements of old and new tubes.

may be obtained for therapeutic use was successful only when a glass was compounded out of low atomic weight materials. The use of this glass in the tube window permits the escape of a quantity of the radiation sufficient to produce useful biological changes when absorbed in the skin.

rate of evaporation. This rate may be extremely small, but where the material evaporating is tungsten, of extremely high atomic weight, even a very minute amount will be of importance if it deposits on the window. The impact of the electrons upon the anode may be sufficient to free a small quantity of

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the material of which the anode is composed. This may also deposit upon the window, adding to the filtering action of the tungsten. It seems probable that the evaporation of tungsten is the most important source of filtering material.

Treatment with the Grenz ray was instituted in this Clinic December 20, 1928. A table of the intensities to be expected at various skin target distances was furnished with the apparatus. These intensities were measured abroad by means of the Küstner apparatus and were given in r-units. After the first tube had been in continuous service for over a year, during which time 260 treatments aggregating 31.38 hours were given with it, the intensity of its radiation was measured. A standard air ionization chamber of the Duane type was used, with a galvanometer to measure the current.

The values found were approximately only 60 per cent of what the tube was supposed to deliver when it arrived. It was apparent that either the method of measurement was at fault, or else the window had become contaminated. In order to determine what had happened, a spare tube that had never been used was installed, and the intensity measurement repeated. It was found that the intensity given by this tube checked within experimental error with the values determined abroad by means of the Küstner apparatus.

More complete measurements were then made with each tube, and are presented graphically in Figure 1. The tubes were both operated at 10 ma. and 9 kilovolts. Successive filters of celluloid, each 1/100 inch in thickness, were interposed in the beams, and the "absorption curves" determined. These curves show that the old tube is now capable of delivering only 57.5 per cent as intense a beam as the new tube. The quality has changed also, as it requires .012 in. of celluloid to reduce the beam from the old tube to half value, whereas it requires only .01 in. to reduce the beam from the new tube in the same proportion. The action of the contaminating material upon the window is, therefore, to reduce the intensity at the expense of the softer, less penetrating part of the radiations. If we make the assumption that the deposition of foreign material on the window of this tube was proportional to the time it was in operation, we can calculate that for every hour of use, the intensity decreased by approximately 1.3 per cent of its original value. This is, of course, only an approximation, and measurements must be made with many tubes before any very general statement can be made. It will, however, serve as a guide in the transfer of dosage when it becomes necessary to change tubes, and may help to explain some of the variations in results that have been reported by different operators using this same type of tube, and apparently employing the same technic.

THE LONG SPACINGS OF RUBBER AND CELLULOSE

By GEORGE L. CLARK, Ph.D., and KENNETH E. CORRIGAN, M.S.
From the Department of Chemistry of the University of Illinois

THE purpose of this investigation was to find a means of attack on the analysis of those compounds some of whose crystal diffraction spacings lie between the ranges of X-rays and the ultra-violet region. In this group the most important at present are rubber and cellulose, although many other uses such as the study of proteins and tissues might be found for such a method.

These compounds in their natural state are made up of aggregates of small units. When examined by the X-ray method, they for the most part give only a diffuse band that is termed an amorphous ring. When stretched or strained (in the case of rubber) or lined up along the fiber axis (in the case of cellulose), these same compounds give a more or less complete fiber pattern, showing that the amorphous ring in reality conceals a true crystalline structure. This crystal structure, as will be shown, has been a continuous source of controversy. Various formulæ for rubber have been proposed, proved, and disproved; cellulose has fared the same way. In each case the parent chemical substance is well known, but what number of units make up the ultimate particle, that is, at what point C_5H_8 ceases to be isoprene and becomes rubber, can not be shown until the unit cell has been definitely measured.

For some time rubber was considered to be entirely amorphous. In 1924 and 1925, however, a number of papers appeared by Clark,[1] Katz,[2] and Hauser and Mark,[3] which indicated a different condition. All agreed that vulcanized rubber gave only the broad amorphous ring; in certain cases raw unstretched rubber was reported as giving interference rings indicative of crystalline structure.

While this work was in progress Plummerer and Koch[4] tried successfully to isolate crystalline material by repeated extraction of raw smoked sheets and purification of the product. They reported the finding of colorless, non-elastic crystals, and, further, an analysis of these crystals. The unit cell dimensions were $4.83 \times 4.71 \times 5.33$, the form monoclinic, the angle between the axes $77° 19'$, and one molecule in the unit cell. This work has not been repeated.

Several investigators, Katz in particular, have tried to crystallize rubber by cooling it to low temperatures. This seems to be unsuccessful in the case of raw unstretched rubber. In the case of the stretched rubber it is generally reported that the crystal pattern formed by the stretching is fixed, and remains after the material has returned to normal temperature.

The examination of stretched rubber gives by far the most important information. The photograph of this shows sharply defined maxima indicative of a fiber diagram superimposed on the amorphous ring. This demonstrates that the crystalline material is not in random orientation, but has assumed the form of long fibers containing all of the crystalline material and oriented along the axis of elongation. Calculations show that the isoprene unit is the basis of the crystalline material. Vulcanized rubber gives the same effect, but the required amount of elongation is greater than in the case of the raw rubber.

[1] Am. Jour. Roentgenol. and Rad. Ther., December, 1924, XII, 556.

[2] Chem. Zeit., April 25, 1925, XLIX, 353. Die Naturwissenschaften, May 8, 1925, XIII, 410. Ztschr. angew. Chem., 1925, XXXVIII, 439. Kolloid-Ztschr., 1925, XXXVI, 300; 1925, XXXVII, 19.

[3] Kautschuk, December, 1925, p. 10. Kolloidchem. Beihefte, 1926, XXII, 63.

[4] Justus Liebigs Ann. d. Chem., 1924, CDXXXVIII, 294.

In the course of their investigation Hauser and Mark accustomed their eyes to the dark by remaining in a darkened room for five hours and then watched the process of orientation by means of a fluoroscope while the sample was being stretched. They found that the interference maxima appeared instantaneously, but that they remained for some time, in certain cases as long as one hour, after the tension had been released.

The primary interest of all the investigators was to find the unit cell of rubber. Katz, as well as Hauser and Mark, calculated unit cells which were rhombic in form from the Hull-Debye-Scherrer rings by use of the Polanyi equation. Katz obtained $8 \times 6.5 \times 6.5$ Å., while Hauser and Mark measured $8.0 \times 8.6 \times 7.68$ Å., the correct dimensions. This would indicate four molecules of isoprene per unit cell, or more, if the spacings are of the second order. Ott[5] examined a specimen of crepe rubber and found the greatest spacing, $d = 6.37$. From the calculated volume of the molecule of isoprene, he decided the unit cell contained six isoprene units. His assumptions in this calculation were attacked by Herzog.

The present status of knowledge of the structure of cellulose has been so thoroughly and excellently covered in recent papers[6,7] that it will not be discussed in the present paper. The latest investigations by Mark and Meyer[8] show that the unit cell is monoclinic with the following definite dimensions: $8.3 \times 10.3 \times 7.9$ Å., $\beta = 84°$.

THEORETICAL

From all the mass of information on these polymerized compounds, rubber in particular, several important theories have grown up. In the first place, it was shown

5Die Naturwissenschaften, 1926, XV, 320.

6Bragg, W. H.: Cellulose, April, 1930, I, 80.

7Clark, G. L.: Ind. and Eng. Chem., May, 1930, XXII, 474.

8Ber. Dtsch. Chem. Ges., 1928, LXI, 593. Ztschr. f. Phys.-Chem., Abt. B2, 1929, p. 115.

that the line breadth of the diffraction pattern did not change with stretching, and therefore that the effective particle size remained the same. From the Debye-Scherrer equation, Clark estimates this particle to contain two thousand molecules of isoprene.

In the usual case a unit cell can not contain less than one molecule of any substance, but it is apparent at once that the cells which have been measured in this case can contain only a small fraction of a long and exceedingly complex chain.

From the fact that the crystals observed upon stretching a sample appear at once, it is obvious that those crystals existed in some other form in the sample before stretching. The theory advanced by several writers is that, upon stretching, the angles between groups in the molecule, the chain being a spiral, are changed, and that in the course of this changing certain groups are brought into such relation with each other that they form continuous planes which diffract X-rays. If this theory is correct, then these planes in reality may have almost nothing to do with the true structure and properties of rubber, a case which is not true. A single point in its favor is the fact that although these planes appear instantly they take some time to disappear. Their appearance would depend only upon the mechanical pull necessary to bring these groups into the proper position, while their disappearance would depend upon the action of comparatively weak secondary valence forces to bring them back.

It becomes apparent, however, that if the true unit cell is to be measured, then stretching must not be employed except as a last resort, and any data so obtained must be interpreted with caution. On the other hand, if a means is perfected to take these measurements in their normal state, there is no question of mechanical interference of this sort.

There are several theories which attempt

to explain the state of molecular aggregation in the amorphous condition. The most logical, advanced by Clark, is that in this case the molecules are in the condition of a regular crystal, *i.e.*, benzoic acid, which has been heated up just below its melting point. In this case a normally crystalline material retains its crystal faces, but when examined by the X-ray method shows no internal crystal structure. It would seem, however, that if this theory were correct, freezing the amorphous material, particularly while it was being agitated in some way to give it a chance to crystallize, should cause it to change over to a definite crystal form. This does not appear to be the case.

A second assumption is that in the original form it is possible that the material exists as preformed aggregates, but since the aggregates are so large the planes are too far apart to enable interference of the rays ordinarily used. The spacing, whatever its nature, is certainly larger than the wave length of the ray, and the limits of interference are unknown. There is almost no firm basis for this theory, but it is the one which the authors hope to prove or to disprove in some definite way.

In the case of cellulose the conditions are somewhat different, since this cannot be considered amorphous. The crystal grains or colloidal micelles have been shown definitely to consist of bundles of long primary valence chains of glucose residues arranged in unit monoclinic cells, with each chain a spiral which has a definite periodic arrangement of the hexagonal rings.

The spacings already found by the X-ray method for cellulose fibers have a long period of 10.3 Å., and, as shown elsewhere in this paper, a monoclinic unit cell can be calculated. Clark has pointed out that this cell contains four glucose residues, arranged in spirals at the corners and along the longitudinal axis. It now becomes obvious that, considering the great molecular weights

which have already been determined for cellulose, this unit does not embody the length of a whole macro-molecule but simply of a definitely recurring period in the micelle. Since the copper radiation cannot be used to measure much longer spacings, the next step is to apply a longer wave length in order to measure a period which may represent the dimensions of the macro-molecule or the micelle.

Since the characteristic radiation of each element increases in length with decrease in atomic number, the use of various target materials below copper in the periodic table would give the desired wave length. The elements which suggest themselves are iron, aluminum, magnesium, carbon, and beryllium. Since the K alpha line for magnesium is at 9.86 Å. (Siegbahn), and this material is readily obtainable in pure form, it was chosen for use in the present investigation.

Since this radiation is easily absorbed by air, some form of vacuum spectrograph was necessary. Such instruments have been designed for work on emission spectra with a very thin window through which the rays from the X-ray tube could enter. It occurred to one of the authors that an instrument might be constructed in which there was no obstruction between the source of the X-rays and the recording film since the two were contained in a single evacuated container. Such an instrument was built and is described in detail.

EXPERIMENTAL

1. *Apparatus.* Two vacuum spectrographs have been constructed. The first consisted of a box of 8.5 cm. square cross-section, 30 cm. in length, inside measurement. One end was permanently closed and the other open. The open end was reinforced all the way around with quarter-inch square brass rod to which the plate which

closed this end could be cemented. At the right side of the closed end a ring 8 cm. in diameter, turned from solid brass and having a deep groove in the exposed side, was securely soldered. A hole was drilled through the side of the box inside this ring. The target was turned of solid brass. It was of the usual form, with water inlet and outlet tubes and cut at an angle of 45°. The face of the target was removable and was held in place with three deep-set small screws. A circular plate 8 cm. in diameter was turned out of quarter-inch brass. The face of this plate was cut with a circular groove and a hole drilled through the center, ⅝ inch in diameter and tapped with a fine thread. A piece of tubing slightly larger than the hole was soldered to the inside of the plate around this hole. The purpose of this tube was to give support to the cathode tube and it was perforated with quarter-inch holes. The cathode tube was made of ⅝ inch heavy brass tubing, and when finished was 30 cm. in length over all. All parts attached to it were brazed, since soldering might not stand the working conditions. The outer end was threaded with the same thread which was used in the cathode end plate, already described. The inner end was fitted with a short heavy screw ¼ inch in diameter to carry the aluminum cathode. The end plate was then run on to this thread part way and the usual air cooling tubes were brazed onto the outside. The insulator was made of 50 mm. pyrex tubing, 25 cm. in length, with ground ends. The cathode was made of aluminum, one inch in diameter with a radius of curvature of 1.5 inch. All brass parts were heavily tinned. (The apparently aimless mixing of units in these dimensions was unavoidable as some of the parts were turned out on a standard lathe while others were naturally measured in metric units.)

A camera of sheet lead was built with a square cross-section just small enough to slip into the body of the tube. This camera carried the usual type of pinhole in the forward end, behind which was a slot for a specimen holder. This specimen holder was made of quarter-inch square brass rod and fitted at top and bottom with small plates held with screws. The specimen was mounted by fastening one end under one of these plates and drawing out the other end to the desired length. The body of the camera as first made gave a length from specimen to film of 15 centimeters. This was later cut down when a longer pinhole was substituted.

The second tube was a modification of the first, built after enough work had been done to show the failings of the first model. The body of the tube consisted of a bronze casting. The camera holder was formed from a large brass tube and the camera from a second tube which would slip inside of the first. These two tubes were fitted by first turning and then grinding. The same target was used but the target angle was changed from 45° to 10°. The important improvements in this tube are as follows:

1. The camera body, being tubular, can not be crushed by the pressure of the atmosphere.

2. Two film holders are provided, one of which has a hole in the center. This one can be set close to the specimen to register the diffraction pattern due to small spacings. The second can be set back in the end of the camera to get great resolution.

3. Connections are provided for two mercury vapor pumps in order to speed up operation and to maintain a higher vacuum while running.

4. Much sharper focus and therefore a more intense beam of X-rays is obtained.

5. The changes in material and construction decrease the leakage by diffusion and make it possible to get any degree of vacuum desired in a reasonably short time.

6. All of these factors of operation

make it possible to obtain pictures in a shorter time and hence with less fogging of the film.

2. *Method of Operation and Results.* Several attempts were made to run the first tube, using a magnesium target. In general, these first attempts were not successful. The primary trouble with the tube was the fact that the flat sides offered too much area to the pressure of the atmosphere and were crushed to the point where some of the soldered seams started to leak. This was overcome by soldering strips of one inch channel iron at about one inch intervals over the surface. Shortly thereafter a successful run was made, using a magnesium target and a tiny chip of calcite for a specimen. A partial Laue pattern was obtained, which proved the presence of the wanted ray.

In order to check the tube a copper target was made and inserted. By replacing the camera and end plate with a plate of aluminum the beam could be observed with the fluoroscope and properly focussed so that a powerful ray was obtained. A carbon target was turned out of high grade graphite and tried once. This work will be carried farther in the future.

The investigation of rubber was then started. All of the samples were thin vulcanized sheets about 0.1 mm. in thickness. Using a magnesium target and operating at 10–20 P.K.V. with a current of 15 ma., patterns were obtained for pure vulcanized rubber without stretching. The time required was ten hours and the distance from specimen to film was exactly 15 centimeters. Although this method fogs the film badly, a sharp intense ring with a diameter of 31 mm. was seen on the film. This beyond doubt indicates the most important spacing within the range of this tube. Several spots appeared which seemed to be intensity maxima, but as yet no information has been obtained from them. The fogging prevented any weaker lines from showing up.

The second tube was used in the work on cellulose and its operation was found to be very simple and satisfactory. A high vacuum was obtained in about one and one-half hours. The pressure was then allowed to rise to the point where the tube would pass sufficient current, and after the preliminary "gassing out" it was found that the current could be held very steady for a long time. In taking the diffraction pattern of ramie, described below, the tube was operated constantly for thirty hours.

For the examination of ramie a very small bundle of fibers, all arranged parallel, was fastened to the pinhole. The fixed filmholder was placed in the extreme rear of the camera at a distance of 17.3 centimeters. The movable holder with the hole in the center was fitted with a film from the center of which a small circle had been cut with a cork borer. This film was set 4.7 cm. from the sample. Three important rings were found on the two plates, and the rear plate had a partial ellipse outside of the other markings. Their diameters were measured as follows: front film, one ring, diameter 11 mm.; rear film, two rings, diameters 12.5 and 20.5 mm.; ellipse, diameter 22 millimeters. The ellipse was about one millimeter in breadth and was measured between the points of half intensity.

3. *Interpretation and Calculation of Results (A. Rubber).*—The diameter of the sharp ring was found to be 31 mm., which gives a value for d of 99.25 Å. Dividing the cube of this spacing by the calculated volume of the isoprene molecule, we get at once about 8,000 C_5H_8 groups per unit cell.

B. *Cellulose.*—As stated before, a single ring, sharp in character and close in to the center, was found on the front film. Since the main beam passes through the hole in this film we do not have the excessive fogging in the center that usually occurs. The entire film, however, is somewhat fogged by general diffusion.

The diameter of this ring was found to be 11 mm., which, assuming first order, leads to the spacing, d = 85.0. This spacing, as will be shown, is open to question.

On the rear film the smallest ring was found to be 12.5 mm. in diameter, which corresponds to a spacing of 274.1 Å. The ring is very slightly elliptical in the direction parallel to the fiber axis. It is of interest to note at this point that spacings of about 150–500 Å. for the micelle length and 20–50 Å. for the cross-section are calculated from line breadths.

The second ring had a diameter of 20.5 mm., which gives a spacing of 168.0 Å. This is apparently the first order of the spacing which is recorded on the front film in the second order. It is possible that these are both higher orders of some spacing that we have not as yet succeeded in resolving from the central beam.

The outermost mark on the film was elliptical in form and had a diameter of 22 mm., giving a spacing of 156.0 Å. This does not correspond with any spacing as yet recorded and probably indicates a new periodicity. The largest diameter of this ellipse is perpendicular to the fiber axis of the specimen, from which we can postulate that this is one of the cross-spacings of the micelle.

This work was the beginning of a complete investigation of long spacings of rubber, cellulose, and other highly polymerized compounds, including proteins and tissues, and will be carried to further and more conclusive results. If in this work it can be assumed that we are measuring the greatest distances in a micelle, then it follows that we have a direct check upon particle size, and it may be possible in the future to take such data and work back to an absolute calculation of particle size from other methods, such as measurement of breadths of diffraction interferences.

SUMMARY

1. A new method for the examination of highly polymerized compounds is proposed. This consists in the direct measurement from diffraction interferences of colloidal micelle dimensions.

2. The construction of an instrument consisting of an X-ray tube with magnesium target and vacuum camera without intervening window or air space is described.

3. The major spacing of unstretched vulcanized rubber is found to be 99.3 Å.

4. The number of isoprene molecules per unit cell is estimated to be of the order of eight thousand.

5. Three measurements of the long spacings of cellulose are recorded.

EXPERIMENTAL STUDIES OF THE MOTILITY OF THE GASTRO-INTESTINAL TRACT OF RACHITIC RATS BY MEANS OF THE X-RAY[1]

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A S is well known, rickets represents one of the important dietetic diseases of early infancy. It is accompanied by a distinctive pathology of the osseous system, as well as by a marked muscular atony affecting not only the skeletal muscles in general but also the smooth muscular structure of the gastro-intestinal tract. It is for the latter reason that in all marked cases of rickets we find a varying amount of dilatation of the stomach and colon.

The present study was undertaken for the purpose of ascertaining by means of the X-rays the comparative motility of the gastro-intestinal tract of the normal and the rachitic rat. It was considered that such observations would be of value in the interpretation of such disturbances existing in the human host.

In the experiments herein reported about 1,500 radiological exposures were made, including both fluoroscopic and radiographic examinations, upon a total of 80 rats, including both rachitic and normal. The animals used in this work were albino rats raised in our colony from the pure Wistar Institute Stock. The normal controls received a diet of yellow corn, whole wheat, green alfalfa, cotton-seed meal, and 50 per cent of powdered whole milk, containing all the known dietary essentials. These animals grew normally, and were in excellent condition, showing no symptoms of disease.

The rachitic animals were fed the following rachitogenic diet, as recommended by McCollum:

TABLE I

Whole wheat kernel..............................33.0%
Whole yellow maize kernel................33.0%
Gelatin 15.0%
Wheat gluten......................................15.0%
NaCl 1.0%
CaCO₃ 3.0%

One hundred grams of this diet contains 1.221 gm. of calcium, and 0.3019 gm. of phosphorus. Weight of ration, Ca:P = 4.04:1. The proteins of this diet are more than adequate in amount, and are of good

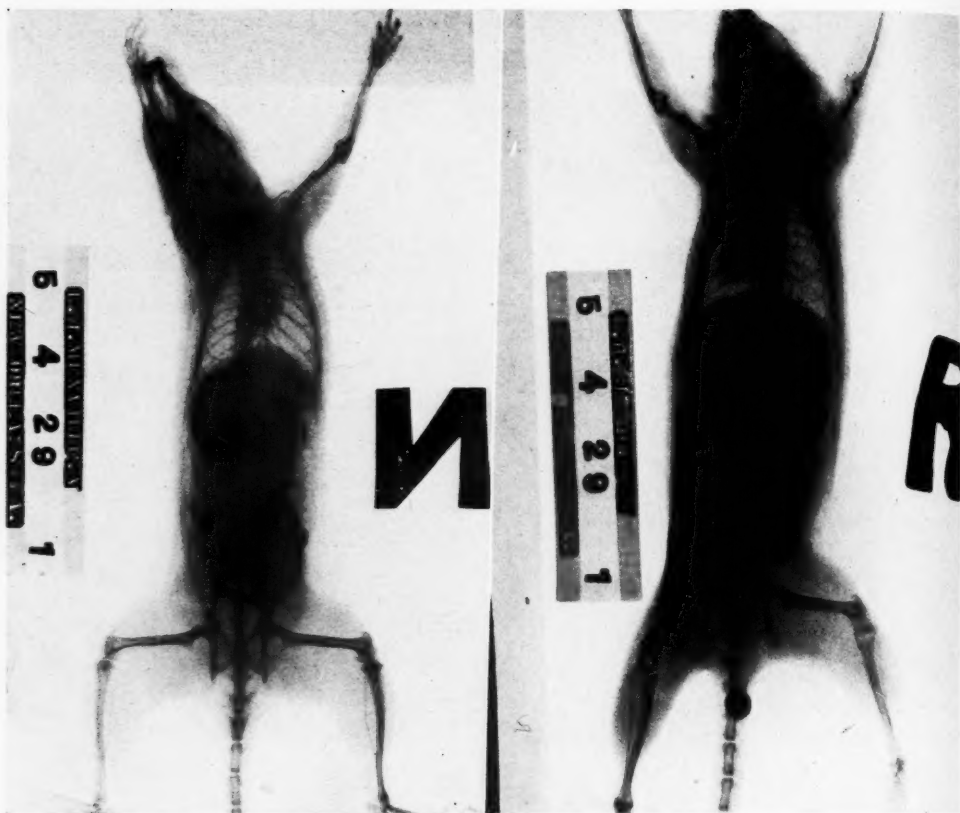Fig. 1. The visualized colon of a rat shown by means of a barium enema.

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Fig. 2. A normal (*left*) and a rachitic (*right*) rat. The stomach of the rachitic rat is markedly dilated and atonic in tone. Both rats were allowed to eat for twenty minutes and roentgenographed at the same time. Note the characteristic bone changes in the rachitic rat.

quality. The calcium content of the ration, 1.221 gm. in 100 gm. of the food mixture, is about double that required for maximum growth. The phosphorus, 0.3019 gm. in 100 gm. of this ration, is far below the amount necessary for the growing rat. When this high calcium, low phosphorus diet is fed to young growing rats for about five or six weeks, they develop an abnormal tottering gait, the animal starting with a hop. In the advanced cases there is a weakness of the posterior extremities.

At this time the animals were examined radiologically in order to ascertain whether or not the osseous changes of rickets were present. Only those animals revealing positive rachitic bone changes were selected for the experiment. A group of normal animals, consisting of litter mates, when possible, together with the definitely rachitic rats were fasted for from twenty-four to thirty-six hours. During this time they were kept in the X-ray laboratory, in order that they might become accustomed to the characteristic noises and to the environment, as we had found in earlier work that rats were easily annoyed and irritated by such noisy surroundings, thereby altering their gastric and intestinal motility.

The normal and rachitic groups were fed a mixture of buttermilk and barium sulphate for twenty minutes in individual
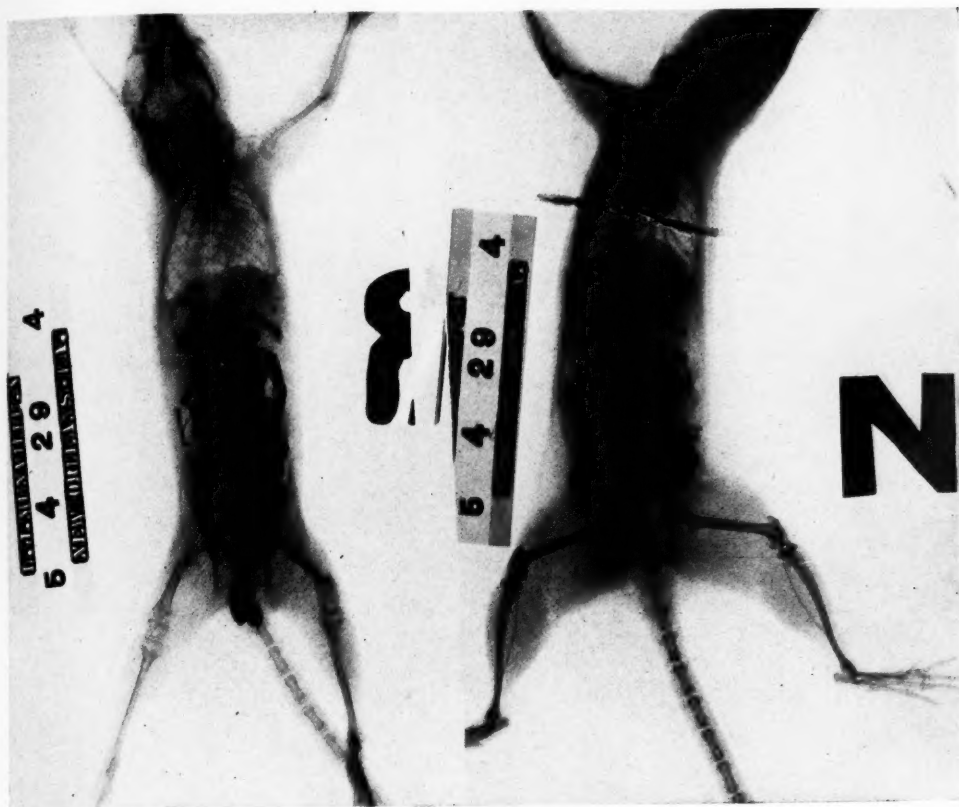
Fig. 3. A normal (*right*) and a rachitic (*left*) rat. The colon of the rachitic rat is markedly dilated and ptosed as compared to the normal rat. Note rachitic bone changes in the rachitic rat. Both rats were fed for twenty minutes and roentgenographed at the same time.

cages, the bariumized meal consisting of 10 gm. of barium sulphate and 10 c.c. of buttermilk. The container and the food were weighed before and after feeding, giving us the amount of food consumed by each rat. Immediately after the feeding, the rats were placed in individual cotton bags, so loosely constructed as to permit free access of air and some freedom of movement on the part of the animal, so as not to produce cramping. This bag method was ideal, as the operator could handle the animal freely while fluoroscoping it without fear of being bitten. Each bag was numbered, corresponding to the individual cage number of the rat. After the feeding, the animals were immediately fluoroscoped and a record of the

findings were made at this time. In some instances it was deemed advisable to make films of rachitic and normal rats, so as to obtain permanent records of the difference in their gastro-intestinal motility. In such instances the rats were fastened by the leg to a wooden frame, to which manner of handling they offered a certain amount of resistance, distinctly affecting in certain instances the motility of the gastro-intestinal tract. Proper records of these disturbances were made. It should be mentioned in this connection that in the fluoroscopic examination, when the bag method was employed, no interference in the gastro-intestinal motility occurred.
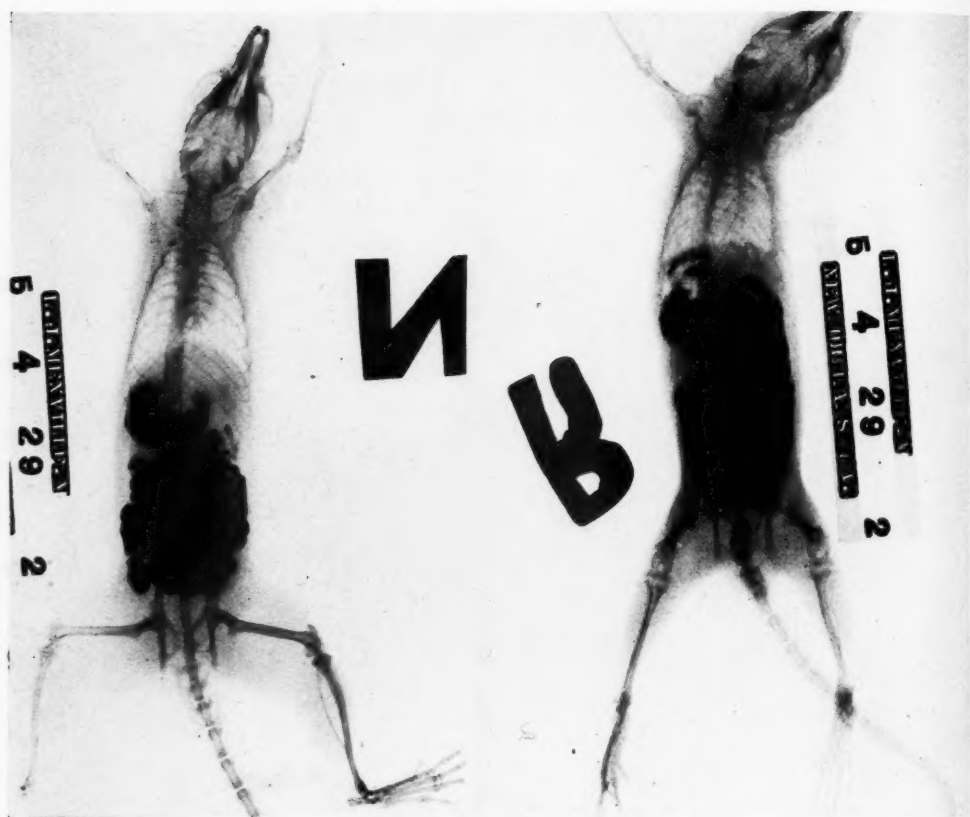
After the first fluoroscopic examination

Fig. 4. A rachitic rat, with characteristic bone changes, and a normal rat. Both were fed for twenty minutes and roentgenographed at the same time. The rachitic rat shows that the food column has already reached the colon, which is massed together and ptosed, while the normal rat demonstrates clearly the loops of small intestines, well separated, and that the food column has not yet reached the colon.

was made of the rats they were placed in their individual cages, from which all traces of food had been removed. This precaution is very necessary, as in our early experiments we found that a few of the rats were obtaining food other than that given them. In one instance we found a small amount of barium sticking to the bottom of the container in which water had been placed for drinking purposes. In another instance we suspected a rat of eating his own feces. We accordingly experimented with two rats, fasting them the usual time, and fed them some feces impregnated with barium. Shortly afterward the fluoroscopic examination revealed barium present in their stomachs. This possibility of error was completely removed for all subsequent experiments.

The fluoroscope was used very freely in our observations of the gastro-intestinal motility in both the normal and rachitic groups. Fluoroscopic examinations of the stomach and small intestine were made at intervals as short as fifteen minutes and as long as one hour. In the observation of the colon a much longer interval of time was employed, on account of the slow emptying of this organ. The stomach, small intestine, and colon of the rat, when filled with a bariumized meal, shows very plainly with the fluoroscope. At first, however, we found

some difficulty in distinguishing between a distended small intestine and the cecum. It was very important for us to be able to make a correct distinction, as we were studying the motility of the small intestine, and the appearance of the food column at the cecum. In order that we might familiarize ourselves with the position, shape, and size of the colon, we proceeded to purge several rats and gave them a barium enema. The entrance of the barium enema was studied under the fluoroscope while the fluid travelled throughout the colon, at which time a plate was made (Fig. 1). We found that the colon of the rat was redundant and had a greater capacity than was anticipated. The colon when filled with the barium enema made clear the position of the cecum and ileum. Table II demonstrates our finding relative to the motility of the gastro-intestinal tract in both the normal and rachitic groups.

An examination of the above table shows that the normal rats weighed more than the rachitic. In spite of the difference in size and weight, the rachitic rats ate 2 gm. more than the normal. The average emptying time of the stomach of the rachitic rats was two hours and forty-six minutes slower than the normal. The average appearance time of the food column in the cecum of the rachitic rats was one hour and thirty-seven minutes earlier than in the normal. The average emptying time of the small intestine in the rachitic group was two hours and nine minutes slower than in the normal group. The average emptying of the colon in the rachitic group was thirty hours slower than in the normal group.
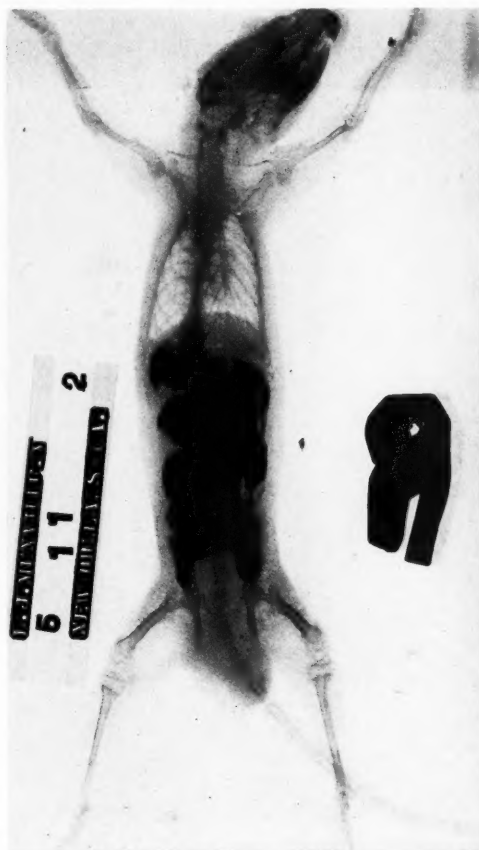

Fig. 5. A markedly dilated colon in the rachitic rat, with an atonic tone, demonstrating beautifully the cause of constipation so often found in cases of rickets.

SUMMARY

The stomachs of the rachitic rats were all dilated and atonic in tone and markedly fish-hook in type, while the stomachs of the normal group were orthotonic in tone and slightly fish-hook in type and showed a marked contrast in tone when compared with the rachitic stomach (Fig. 2). From

TABLE II

	Average Normal	Average Rachitic
Weight of rat	184 gm.	103.1 gm.
Weight of food	6.3 gm.	8.3 gm.
Stomach emptying time	7 hrs. 4 min.	9 hrs. 50 min.
Appearance in cecum	3 hrs. 19 min.	2 hrs. 22 min.
Small intestine emptying time	10 hrs. 36 min.	12 hrs. 5 min.
Colon emptying time	65 hrs.	95 hrs.

observing the early appearance of the food column in the cecum of every rachitic rat, we believe that this demonstrates an apparent hypermotility of the small intestine of the rachitic rat. While we note (see Table II) that the small intestine of the rachitic group empties slower than in the normal, we believe this to be due to the larger amount of food it has to discharge and not to a true hypomotility. The colon of the rachitic group shows a marked hypomotility, however, as evidenced by a dilatation and a very slow emptying time, as well as a ptosed position when compared to the normal group (Fig. 3). The stomach of the rachitic group shows a marked retardation in its motility when compared with the normal group. The atonic and dilated colon observed in these experiments, as shown in Figure 2, demonstrates beautifully the cause of the constipation so commonly found in rachitic subjects.

FORMULÆ FOR THE RAPID CALCULATION OF MILLICURIES OF RADON (EMANATION) DESTROYED AND DOSAGE DELIVERED

By HYMAN I. TEPERSON, M.D., BROOKLYN, NEW YORK

WHEN treating a lesion with radon we must first determine the number of millicuries of radon which will have to be destroyed in order to deliver the desired dose. For example, if we decide to deliver a dose of 6,000 millicurie-hours to a carcinoma of the uterus, and each millicurie of radon delivers a total radiation of 133.3 millicurie-hours when destroyed, we must divide the 6,000 by 133.3 to determine the number of millicuries required. Although the mathematics involved is elementary, still, when a number of cases have to be figured for, it is time-consuming. A simple formula which reduces the calculation to a mental process is as follows:

$$\text{Formula}: \frac{3}{4} \times \frac{\text{mc. hr. (dose)}}{100} = \text{mc.}$$

destroyed.

$$\text{Example}: \frac{3}{4} \times \frac{6000}{100} = 45.$$

To divide by 100, cross off the last two figures and then take ¾ of 60, which equals 45 millicuries. This is the exact amount of radon required and can be proven by multiplying 45 by 133.3.

When using seeds, which are permanently implanted, we obtain their full possible radiation, and, therefore, the number of millicuries of radon with which we start is equal to the number of millicuries of radon destroyed. Ordinarily if we wish to calculate the total dose delivered after complete decay we multiply the number of millicuries of radon by 133.3. A short-cut is the following formula:

Formula:

$$\frac{4}{3} \times \text{mc. radon} \times 100 = \text{mc.-hr. (dose)}$$

Example: What is the total radiation delivered by 45 mc. radon when fully decayed?

$$\frac{4}{3} \times 45 \times 100 = \text{mc.-hr.}$$
$$\frac{4}{3} \times 45 = 60$$
$$60 \times 100 = 6{,}000 \text{ mc.-hr.}$$

Many radium workers follow the method of Regaud, using small amounts of radon over longer periods of time. Four days is the average time of application in our clinic. Fifty per cent of radon is destroyed in four days (3.85 days, to be exact), so that if you wish to deliver the above dose or any given dose in four days, you start with twice the amount of radon which is calculated to be destroyed. Using the same figures as in the above example and by substituting the fraction 2/3 for the fraction 4/3 we get the radiation of half decay (3.85 days).

Formula for half decay period:

$$\frac{2}{3} \times \text{mc. radon} \times 100 = \text{mc.-hr.}$$
$$\frac{2}{3} \times 45 \times 100 = 3{,}000 \text{ mc.-hr.}$$

3,000 mc.-hr. is the dose delivered in four days.

The numbers used, it will be noted, are multiples of 100, but a little familiarity with these formulæ will enable one to calculate numbers in fractions of 100 with equal facility.

SUMMARY

The formulæ given below have proven of aid for radon calculations.

1. Radon destroyed:

$$\frac{3}{4} \times \frac{\text{mc.-hr. (dose)}}{100} = \text{mc. destroyed.}$$

2. Full decay radiation:

$$\frac{4}{3} \times \text{mc. radon} \times 100 = \text{mc.-hr. (dose).}$$

3. Half decay radiation:

$$\frac{2}{3} \times \text{mc. radon} \times 100 = \text{mc.-hr.}$$

CASE REPORTS AND NEW DEVICES

STEREOROENTGENOGRAPHY OF THE MASTOIDS

By W. O. WEISKOTTEN, M.D.,
SAN DIEGO, CALIFORNIA

There is some difference of opinion among roentgenologists as to the proper method of making an examination for suspected mastoid pathology. Rather elaborate equipment has been designed with the idea of properly centering the tube and cassette to take advantage of angles which are necessary for the proper projection of the mastoids on the film. Any method which will produce a pair of films showing the greatest contrast and detail of the fine cellular structure of the mastoid, and which is easy to use in everyday practice without the necessity of having especially designed and complicated apparatus, should be the method of choice. For those who still believe that mastoid films made without the Bucky diaphragm give more information and are easier to make, the following method, of course, would not be of interest. However, if routine skull films for suspected fracture or bone pathology are better made with the diaphragm, it is reasonable to assume that the function of the Bucky diaphragm should be applied to the making of a mastoid examination which requires the greatest detail of fine cellular structures. By the same token, we believe that stereoscopic films of both sides for comparison give more information than a pair of so-called "flat" films. There is absolutely no standard as to mastoid development at any given age, but, fortunately, Nature usually makes the mastoids similar in structure in each individual, until pathology develops. The value of comparison, then, is obvious. It takes little additional time and only the cost of one
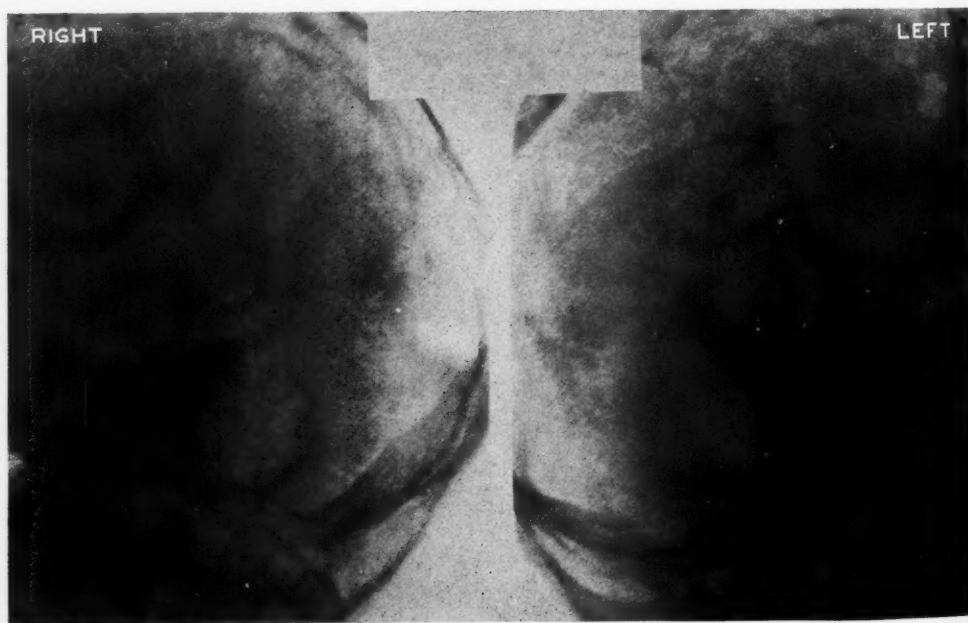

Fig. 1. One of a pair of mastoid films illustrating the method outlined.

8 by 10 film to complete the mastoid examination properly, if stereoscopic films are made, and this extra time and expense is more than offset by the satisfaction of knowing that nothing is being omitted when films of diagnostic quality are so essential.

In order to standardize the method of exposure and to be able to routinely duplicate the mastoid films, a simple scheme for placing the cassette in the Bucky diaphragm tray is necessary. An L-shaped piece of hardwood, one inch wide, the thickness of the cassette, and with the two sides of the right-angle measuring nine and four inches, respectively, is used as a guide. Two screws, with heads countersunk into the wood, project about one-sixteenth of an inch through the long leg of the wooden angle guide. The 8 by 10 cassette is divided equally by a pencil mark and the center of the left-hand half of the film is accurately centered on the metal tray of the diaphragm. Two holes are drilled through the metal tray to correspond with the screws which project through the wooden angle guide. This guide fits against the lower right-hand corner of the cassette. The 8 by 10 film is then moved towards the opposite side, until the remaining half of the cassette is accurately centered on the tray and two more holes are drilled for the projecting screws of the guide. The center of the 4 by 5 half of the cassette should now correspond with the absolute center mark on the top of the diaphragm. The cassette and guide are now moved back to the first position.

The patient is placed prone on the Bucky table, with chest flat. The left ear is folded forward and the center of the mastoid is placed on the center point of the top of the Bucky diaphragm. The face is inclined towards the table approximately fifteen degrees, and the distance from the tip of the nose to the top of the Bucky is measured. The 8 by 10 film is placed against the guide in the first position and the near side of the

cassette is covered with a piece of sheet lead accurately cut and with one edge turned down in order to hold the lead in place. The tube is tilted fifteen degrees towards the feet and accurately centered through the
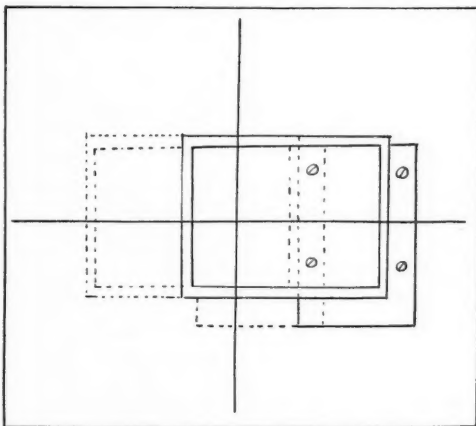

Fig. 2. Metal Bucky diaphragm tray. The cross lines show the center of the diaphragm and the center of half of an 8 by 10 cassette. The dotted lines indicate the second position of the cassette and the wooden angle guide. Sheet lead covers one-half of the cassette in each position.

mastoid to the center of the Bucky top. The tube is now shifted one and one-fourth inches towards the feet, and the first exposure is made. The exposed portion of the first cassette is marked with a pencil and the second cassette is placed in position with sheet lead covering the near half. The tube is now shifted two and one-half inches towards the head (one and one-fourth inches from center position), and the second exposure is made. The cassette is now moved over for the opposite mastoid, with angle guide moved to the second position, which accurately centers the cassette. The lead sheet is now placed over the exposed half of the cassette. Cautioning the patient not to move the chest, the head is rotated carefully, and, with the right ear folded forwards, the right mastoid is centered on the central point of the Bucky top. The distance from tip of nose to top of Bucky is made to correspond with the opposite side.

to insure the same angles for the projection of the two mastoids. Exposure No. 3 is now made, with the tube in the same position as for the second exposure. Both halves of the second cassette are now exposed and the unexposed half of the first cassette is centered by means of the angle guide. The lead covers the first exposure and the tube is shifted towards the feet, or back to its original position. The fourth exposure is now made. The left and right sides are identified with suitable markers at the time of each exposure, and when the films are processed and placed in the stereoscope, the mastoids appear side by side with three dimensions, giving infinitely more information than a pair of "flat" films. The angles used are essentially the standard "fifteen degrees towards the face and fifteen degrees towards the feet." With proper exposure factors of time, milliamperes, and kilovolts, and with a twenty-five to thirty inch target film distance, satisfactory films will be obtained every time this method is used. Of course, a fine focus tube gives better detail than a tube with a broad focal spot. The whole method is simple and rapid, and the operator is rewarded with a pair of films which will allow accurate interpretation. The relation of tube stand to Bucky diaphragm should be permanently established, and with position of cassettes determined, the only variable factors are the position of the patient and variation in exposure to compensate for individual skulls.

No originality is claimed for the method of making stereoscopic mastoid films side by side on two 8 by 10 films, but the details of standardizing the procedure have been worked out with the idea of consistently producing diagnostic films with the least amount of trouble, and with the equipment found in any general X-ray laboratory.

One of a pair of films is shown (Fig. 1) and the accompanying diagram gives an idea of how the cassettes are placed on the metal Bucky tray.

MEASUREMENT OF CURRENT DURING SHORT EXPOSURES

By M. M. SCHWARZSCHILD, M.A.,

Physicist, Beth Israel Hospital, New York City

Recently there has appeared in Germany a ballistic milliamperemeter. The instrument is produced by Hartman and Braun and permits the measurement of current flowing for very short periods of time. Prior to the announcement of this new meter the author devised a circuit, herein described, which makes possible such measure-
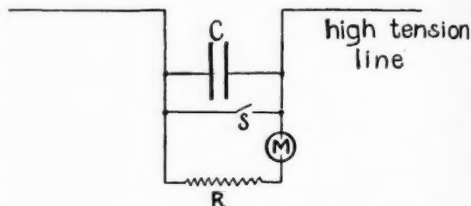

Fig. 1. Circuit of milliampere-second meter.

ments with apparatus readily available at a reasonable cost. Because of the simplicity of the arrangement it ought to be of interest to those who wish to control rapid exposures.

The elements of the circuit are shown in Figure 1. C is a condenser of high capacity; in the author's model it consists of 25 paralleled condensers of 10 microfarads each, capable of withstanding 200 volts. R is a resistance, in the present model, 200,000 ohms. M is a milliamperemeter. In the present model the full scale deflection is 1 milliampere. S is a simple switch. The device is connected as indicated, in series with the tube, and must, of course, if there is no center tap on the transformer, be mounted on an insulated support.

The operation of the device is as follows: Prior to making an exposure the switch S is closed for about a minute in order to completely discharge the condenser. The switch

is then opened and the exposure made. Practically the only current flowing through the device is the charging current of the condenser, so that at the close of the exposure the condenser is charged. The voltage of the charged condenser is readily seen to be $\dfrac{1000\,i\,t}{c}$ where i is the current through the high tension circuit in milliamperes, t is the time of the exposure in seconds, and c is the capacity of the condenser in microfarads. Due to this voltage difference a current will flow through R and M after the exposure is ended. This current in milliamperes is evidently equal to $\dfrac{i\,t}{c\,R}$ where i, c, and t have their previous meanings and R is the resistance in ohms. Evidently, then, the current indicated on the meter M is a direct measure of the product $i\,t$, or the milliampere-seconds of the exposure.

The values of R and c are so selected that the time constant of the discharge through R is such that the drop in current during the first second after the exposure is inappreciable. In the case here considered the drop in current, and hence in the reading of M after one second, is only 2 per cent of the total deflection. It is thus a simple matter to read the meter quite accurately.

The maximum range of the instrument is fixed by the breakdown voltage of the condenser battery which must not be reached. The range in milliampere-seconds is given by $\dfrac{Vc}{1000}$ where c is the capacity of the condenser battery is microfarads and V the maximum safe D.C. voltage of the condenser. In the case here considered the maximum range is 50 milliampere-seconds.

Condensers of the high capacity desirable here are easily obtainable at radio shops, since they are important elements of the ordinary radio battery eliminators. The rated value for the capacity cannot be relied on, so that the device should be calibrated with known exposures.

A series of measurements made with this device and a synchronous timer shows very good agreement on longer exposures (1/30–1/4 sec.), but the agreement is not quite so good for shorter exposures, there being
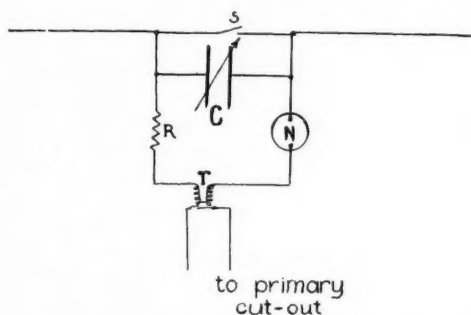

Fig. 2. Circuit of proposed milliampere-second timer.

always a disproportionate rise for the shorter exposures. In order to test the apparatus to decide whether this apparent discrepancy is due to a defect in the device or to actual change in output of the X-ray machine, the radiation output was measured with an ionization chamber. The deflections for short exposures were too small to permit of accurate reading, so that readings were taken at longer intervals, and then at the same exposure for repeated short periods. A set of test runs on the device and on the ionization chamber resulted as follows: The meter showed an increase of 20 per cent in current for an exposure of 1/120 sec., as against one of 1/4 second. The ionization measurement showed an increase of 13 per cent in ionization for 30 exposures of 1/120 sec. each, as against a single exposure of 1/4 second. Exact agreement could not be expected as the two methods measure very different quantities, but there is undoubtedly a difference betwen the circuit behavior at short exposures as against long ones. The differences are probably due to the fact that for very short exposures (1/120–1/30 sec.)

transient phenomena enter into the operation of the high voltage system, so that the milliampere readings taken with an ordinary trolled by the number of milliampere-seconds, rather than by the time alone. This suggestion is made without any actual ex-

Fig. 3.   Present model of milliampere-second meter.

milliammeter cannot be trusted. If this is the case, a method of exposure control involving the use of a system of this kind, or of a ballistic milliammeter, is highly desirable.

This device may be modified in such a way as to make it an effective milliampere-second timer, so that exposures can be con-

perience with such an arrangement, but with full confidence as to its practicability. The circuit for such an arrangement is shown in Figure 2. N is a neon or other gas tube having a definite breakdown voltage. R is merely a protective resistance for the tube and the relay r, which operates a primary cut-out. The whole system is connected in

the place of, or in series with, the milliam-meter, where the latter is at ground poten-tial (center tapped transformer and recti-fier). The condenser C is made variable so that it may be set for different exposures. When the exposure has progressed to the desired point, the condenser discharges through the neon tube and relay, thus open-ing the primary circuit. Such a timer would be extremely accurate, and would, by its very nature, compensate for fluctuations.

PORTABLE RADIOGRAPHIC AUTOPSY EXAMINATION

By PAUL F. TITTERINGTON, M.D., ST. LOUIS

During the St. Louis cyclone of Septem-ber, 1927, a workman for one of the large factories was killed. Eighteen months later, the exact cause of death was a disputed question. An autopsy committee was ap-pointed to determine whether death had been caused by direct violence or by burns from bursting steam pipes.

The condition of the body at the time of death prevented thorough embalming. Upon exhumation, it was found that the poor state of preservation prevented the body's removal from the casket.

All exposures were made on films loaded in cardboard holders so that they could be discarded after use. The exposures of the shoulders, entire spine, pelvis, and legs were made through the bottom of the casket on films placed under it. The upper portion of the body could be raised sufficiently high and fixed in position so that the head ex-tended above the sides of the casket. Films were then placed at the sides of and under the skull.

The machine used was a five-inch G. E. portable with a thirty-milliampere radiator tube. The exposures varied from thirty to seventy-five seconds at a forty-inch distance.

Fig. 1. Right leg, showing fracture. Exposure was made through the casket.

The radiographic findings are of interest. The thoracic and abdominal viscera had been removed and the cavities packed with formaldehyde sawdust. The roentgenogram of the chest had the appearance of a mili-ary tuberculosis, due to the sawdust. No diaphragms were demonstrated. A large
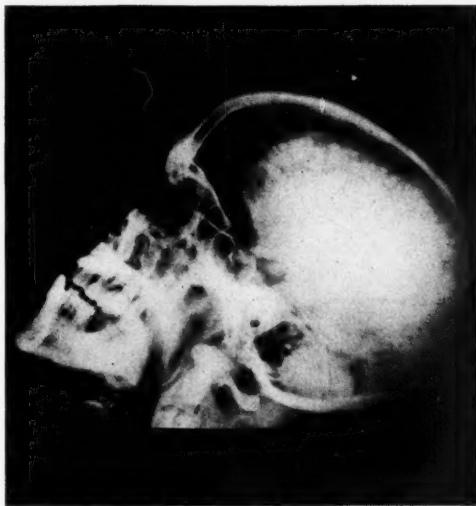

Fig. 2. Skull, showing shrinkage of the brain.

hemostat (left by the undertaker) was seen in the right chest. It was found to be attached to the right subclavian artery.

The bones of the spine and pelvis lacked fine detail, but it could be seen that they were all in good alignment and contained no gross fractures. The examination of the skull showed no fractures. The brain was considerably shrunken and the convolutions were quite distinct.

The only pathology from a radiographic standpoint was a compound fracture through the middle of the right tibia and fibula.

This examination was conducted in the fieldhouse of the cemetery, with the thermometer fortunately standing close to zero.

ROENTGEN THERAPY OF GIANT-CELL TUMOR AND OSTEITIS FIBROSA CYSTICA[1]

By L. T. Le WALD, M.D.,
Professor of Roentgenology, New York University

I want to confirm the excellent results obtainable in the treatment of giant-cell tumor and osteitis fibrosa cystica by roentgen therapy, without any disturbance in the growth of the bones involved. I have four cases in different regions in young subjects.

Case 1. A boy aged 11 years (see Figs.

[1]This material was presented in discussion of the paper on "Osteogenic Tumor: Growth Injury of Bone and Muscular Atrophy Following Therapeutic Irradiation," by Arthur U. Desjardins, M.D., before the Radiological Society of North America, at Toronto, Dec. 2–6, 1929.

Fig. 1-*A*. Case 1. Osteitis fibrosa cystica of the right humerus.
Fig. 1-*B*. The same case, three years and two months after roentgen therapy. There has been no disturbance in growth.
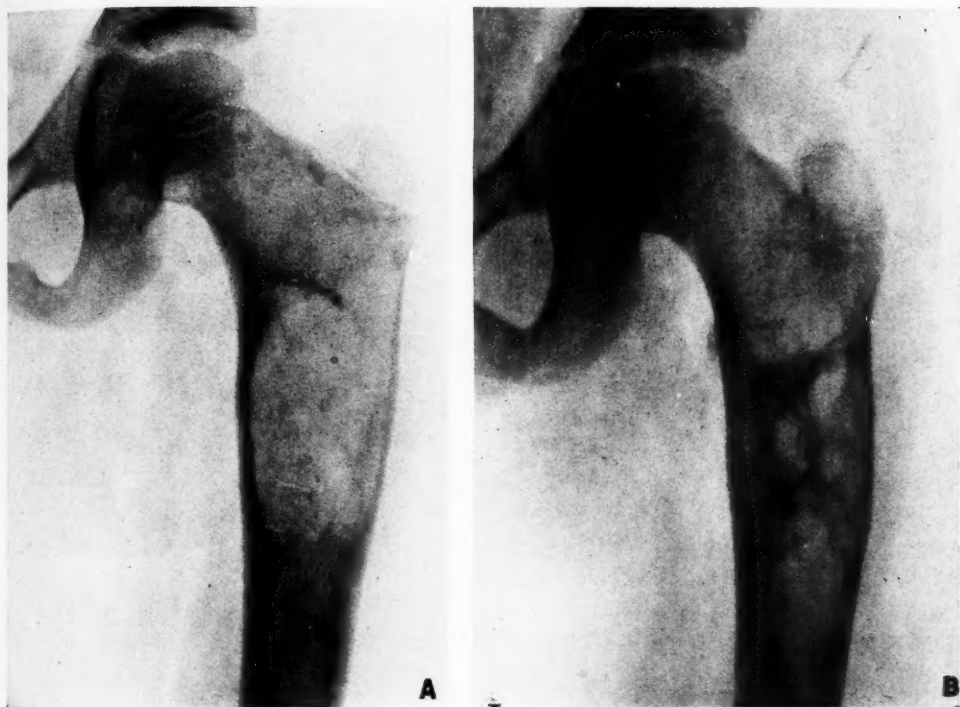
Fig. 2-A. Case 2. Osteitis fibrosa cystica of the upper third of the right femur.
Fig. 2-B. The same case, two years and ten months after roentgen therapy. There has been no disturbance in growth.

1-A and 1-B) had a very extensive cystic lesion in the upper half of the humerus. There was no biopsy. Microscopical examination of material from curettage showed osteitis fibrosa without giant cells. He had a fracture; he was curetted; he had two other fractures, and then he had X-ray treatment with moderate voltage (120,000), filtered through 4 mm. aluminum. Now the lesion has filled in and the boy is cured. Seeing this paper on the program by Dr. Desjardins, I made roentgenographs of the humerus the other day to show that there is no disturbance in growth. This lesion has filled in almost completely with fairly uniform bone, except for some smaller areas of lesser density in between. I made roentgenographs of his other side last week for comparison, to see if we could detect any change

at all in the epiphyseal region, and there was none. There is no disturbance at all in the length of the bone.

Case 2. A girl of seven and a half years had a very similar type of lesion in the upper third of the femur (see Figs. 2-A and 2-B). The lesion was discovered because the child limped to some degree. She had no fracture and no operation was done. The lesion has filled in very satisfactorily. The epiphyseal region was probably just out of the field, although not screened off so carefully but that it did get a certain amount of radiation. There is no difference in the growth of the lower extremities.

Case 3. Female child, aged 8 years. A tumor in the lower end of the fibula that was all ready to break through the cortex but had not done so, was given X-ray treat-

ment. There was distinct improvement, re-
sulting in a thickening of the cortex and a
beginning filling in of the areas of rarefac-
tion. In this case there is no change in
growth, a year later.

Case 4. Male child, aged 11 years. This
case is one I showed a year ago, and some
of you may be interested in seeing an X-ray
film made a year later (Fig. 3-*A*). This
was a very large expanding tumor at the
lower end of the radius. It was given
treatments with medium voltage at weekly
intervals from three sides, five minutes for
each area at each weekly sitting. It re-
sponded very favorably. Now the epiphys-
eal region was distinctly radiated in this case
and growth was not disturbed. The tumor
has shrunken down and filled in with bone
except for a few areas (Fig. 3-*B*). A com-
parison of the two sides shows that the bone
is practically normal from the epiphyseal
line down for about two inches. There are
still one or two very small rarefied areas
which I think we can disregard so far as
likely to give any trouble in the future. The
patient had treatment for about a year and
a half, and now it is a year and a half since
treatment ceased. There has been no dis-
turbance in the growth of the bone in this
case.

Fig. 3-*A*. Case 4. Giant-cell tumor of the lower end of the right radius.

Fig. 3-*B*. The same case, three years and five months after roentgen therapy. There has been no disturbance in growth.

Dr. Desjardins is to be congratulated on
the excellent therapeutic result in his case.

CONCLUSIONS

Benign giant-cell bone tumors, or osteitis
fibrosa cystica, can be satisfactorily treated
by moderate voltage X-ray. Biopsy is not
essential, as the response to the X-ray treat-
ment may be taken as a confirmation of the
X-ray diagnosis.

EDITORIAL

JOINING HANDS IN RESEARCH AND IN A NEW "RADIOLOGY"

With this first number of a new volume there begins also a new chapter in the scope and service of RADIOLOGY. Its activities have been confined through the years to the medical science of radiation, particularly X-rays, because that was the purpose for which it was created. In the opinion of disinterested observers the journal has recorded faithfully notable research efforts and reflected progress in technic and advancement in theoretical knowledge. Most of the contributors have been members of the medical profession who necessarily had to combine in their own training and experience as many branches of the many-sided science of X-rays as possible, the interest, however, being in improved diagnostic and therapeutic applications.

Contemporary with these medical researches have been those in laboratories of the other sciences. The physicist has been interested in the radiation as such, the measurement of spectral wave lengths, determination of the laws of emission, absorption, and scattering, and the relationship of experimental facts to the structures of atoms. The chemist has come to use X-rays as one of the greatest new tools in the study of the ultimate fine structure of matter, and, of course, he has been further concerned with the effect of X-rays upon chemical reactions as a part of the rapidly growing branch of photochemistry. The biologist has largely confined his use of X-rays to the field of genetics, the effects of irradiation on growth, reproduction, and characteristics of future generations. More recently we find sprouting a tremendous industrial science of X-rays in which fundamental properties of these rays, such as the penetrating power, employed for thirty years in medical radiography for diagnosis and now for examining the interior texture of any material from cast steel to golf balls, and diffraction by solid crystals, are utilized in the solution of difficult research problems and for routine testing of manufactured articles.

It is inevitable that the science of X-rays has become so ramified that the various branches have little or no contact with each other. Men become expert radiologists in one field and yet remain in ignorance of the problems and achievements of other men using the same radiation to different ends. The inevitable result is overlapping of effort and a progress towards the goal of knowledge which is delayed and incomplete. More and more in this complex age of civilization and of specialization in some narrow corner within a sub-branch of some science, is growing the *clinical idea*—a joining of effort with each specialist contributing to the common cause of science his own best efforts and his own experimental observations. It cannot be expected that the medical radiologist or roentgenologist should be able to combine in himself expert knowledge of anatomy, physiology, histology, photochemistry, physics of radiation, engineering details of equipment and other specialized research fields, any more than the physicist should know cell structures or the chemistry of protoplasm.

After all, however, the medical applica-

tion of X-rays—diagnosis and alleviation or cure of suffering—transcends all others. Back of all the X-ray research on extending accuracy of wave length measurement to a few more decimal points, or on analysis of the ultimate structure of steel, or rubber or anything else imaginable is the hope that some new fact or phenomenon may come out which may be useful where the human body is the specimen. And yet there has been little or no opportunity for the radiologist to learn what the X-ray chemist or physicist or biologist or engineer is doing and could do in helping to solve medical problems, the most difficult and important of all, unless he should read papers scattered widely through all sorts of American and foreign journals. Similarly, the research chemist and physicist has had little opportunity to learn wherein he can contribute information and expert assistance in rendering radiology and roentgenology more exact sciences.

To introduce the *clinical idea of research,* to enable joining of hands and of effort by mutual acquaintanceship, mutual interchange of results and dissemination of information of interest and value to all, and to further the science of X-rays and related radiation in general and the medical applications in particular to greater achievements in behalf of human welfare, are the motives involved in the expansion of RADIOLOGY which has been made possible through the generosity of the Chemical Foundation and the keen vision of its responsible authorities. The former scope of the journal has been widened and deepened by the addition of a research division. In selecting the advisory staff of this division to include interests along every line of radiation research, the department editor made bold to choose names of unquestioned international reputation, and not a single rejection was received. This in itself is evidence of the long-standing need for co-operation and of the unself-

ish spirit of research which is now brought into fruition. Because of irrepressible faith in the science it is the hope to make of RADIOLOGY the greatest journal of its kind, transcending the boundaries of any nation and of any science by bringing within its covers accounts of all great discoveries and every detail of progress in the use of a great research instrument.

At first sight the roentgenologist may wonder what concern he has with X-ray crystallography. Let him but read thoughtfully in this issue the masterly and inspiring introductory paper by Dr. J. D. Bernal, of the University of Cambridge, England. He will understand then not only the vast importance of the field but also the actual application directly to the structure determination of tissues in the human body as X-rays carry us to an undreamed-of science of super-histology and an entirely new method of diagnosis. Every reader, whatever his interest, will find highly useful the paper by Dr. R. W. G. Wyckoff, of the Rockefeller Institute, in which is described in detail a remarkably efficient, essentially home-made X-ray tube for general research purposes. Dr. Glasser, already a familiar figure to the readers of RADIOLOGY, presents his great paper on the measurement of γ-rays. And so with other papers, these are but indications of the ideals and ambitions which shall make of RADIOLOGY a greater and more versatile handmaiden of science and servant of mankind. The journal remains the official organ and property of the Radiological Society of North America, but with fine vision the Society has understood and answered the challenge for greater opportunities and wider usefulness.

Under the frontispiece of "Chemistry in Medicine," a portrait of a beautiful little girl, Patricia, daughter of Mr. and Mrs. Francis P. Garvan, appear these words: "May the memory of lost children urge us on." This child lost her life because science

had not advanced far enough to save it. With abiding faith in the immensity of things unfolded by scientific research, these parents and the Chemical Foundation have now made it possible for us to accept the challenge and through the medium of a greater RADIOLOGY as a common meeting ground, to move on to undreamed-of heights of scientific achievement.

GEORGE L. CLARK, PH.D.

THE RÖNTGEN MEMORIAL

It is proposed by the Rheinisch-West-fälische-Röntgen Society, through its founder and President, Prof. P. Krause, in Münster, that a life-size monument of Röntgen be erected in his birthplace of Lennep. The city of Lennep has given the most beautiful spot in the town for this purpose, and the cost of the monument is being raised by voluntary subscription.

American roentgenologists are invited to contribute to this fund, and it is hoped that a sum of $2,500, which is a quarter of the cost of the monument, can be raised in this country. Upon consultation with the Presidents of the Radiological Society of North America and the American Roentgen Ray Society, it was decided to send out letters asking for donations. Thirteen hundred and eighty letters were sent to radiologists on March 15, 1930. Over a hundred generous contributions have been received, the total sum collected thus far being $900. It is hoped that the remaining $1,600 will be contributed by the 1,200 roentgenologists who have not yet responded.

Checks should be sent to Otto Glasser, Ph.D., Cleveland Clinic Foundation, 2050 E. 93rd St., Cleveland, Ohio. The funds which are collected will be transferred to the "Denkmalsfonds der Rhein, Westf. Röntgengesellschaft" of the "Deutsche Bank, Duesseldorf," and the names of the contributors will be sent to Prof. P. Krause, 3 Westring, Münster, i. W., Germany.

PROGRAM OF THE EDUCATIONAL COMMITTEE FOR 1930

1. To encourage the members, officers, and counsellors of the Radiological Society of North America to present educational material before lay audiences and to the general medical profession. Also to present editorials in our own journal RADIOLOGY and especially in other medical journals going out to the general medical profession. These talks, editorials, or papers should tend to bring out the thought that the practice of radiology is a specialty and that the radiologist is a physician and a medical specialist.

2. To encourage presentation of editorials in RADIOLOGY which point out that radiological practice is a medical specialty and that the radiologist should make every effort to qualify as a specialist in radiological work.

3. To disseminate propaganda tending to educate the public to the fact that the average physician or surgeon cannot do as good radiological work as the specialist in radiology.

4. To carry on investigation by correspondence of reported cures for malignancy and the results of research and experimental work being done in malignancy, results of this investigation to be given to the membership of the Society through RADIOLOGY.

5. To encourage the membership to send in to the Committee material of an educational nature tending to help radiology. The Educational Committee will see that this material is published through the various periodicals of the country, both lay and medical.

6. To endeavor to secure the co-operation of the American Medical Association.

the College of Physicians, and the College of Surgeons in a campaign tending to put before the general profession that the radiologist is also a physician. As he is a duly qualified medical man and also a specialist in radiology the profession should expect radiological work of the highest quality.

7. To continue our educational work through the lay press and the periodicals of the country which was started last year. This educational work should also tend to show that the radiologist is a qualified medical man.

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B. C. CUSHWAY, M.D.
ALDEN WILLIAMS, M.D.
W. W. WASSON, M.D.
Committee.

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THE AMERICAN SOCIETY OF RADIOGRAPHERS

The seventh annual meeting of the American Society of Radiographers was held at the Sherman Hotel, Chicago, Illinois, April 28, 29, 30 and May 1, 1930.

The decision was made at the meeting to change the name of the organization from the American Association of Radiological Technicians to the American Society of Radiographers.

A committee was appointed for the purpose of investigating the proper procedure for raising the standards of the Society and, also, a committee to take up the matter of affiliation of the British Society of Radiographers, the Canadian Society, and others, with the American Society of Radiographers.

Papers on technical subjects, pertaining to the radiographers' art, were presented by members of the Society and medical men. These papers will be published in the official journal of the American Society of Radiographers, *The X-Ray Technician.*

From the following partial list of subjects and speakers it will be seen that the whole country is represented and the range of subjects covered of practical application: R. S. Landauer, Ph.D., Chicago, "Discovery and Early History of X-rays"; C. Turner, Chicago, "Development and Early History of Transformer which Makes X-rays Possible"; C. J. Bodle, R.T., Winnipeg, Man., Canada, "Voltage Measurement in Radiography"; Albert C. Nelson, Chicago, "Development and Design of X-ray Apparatus"; H. H. Ingram, Rochester, N. Y., "Fundamentals of X-ray Photography"; V. C. Baldwin, R.T., Covington, Ky., "Dark-room Procedure"; Sister M. Catherine, R.T., Iowa City, Iowa, "Radiographic Chemistry"; Isabel Rutter, R.T., Uniontown, Penn., "Practical Application of Roentgen Ray in Mastoid Technic"; H. O. Mahoney, Chicago, "Analyzing a Poor Radiograph"; Augusta G. Thomas, R.T., Memphis, Tenn., "Clinical Photography"; J. S. Cowles, St. Louis, "Controlling Factors of Dark Room"; Lavilla M. Perry, R.T., and E. S. Newton, Salem, Oregon, "Rib Position and Radiographic Technic of Mid-axillary and Mid-clavicular Lines"; Sister M. Maxentia, R.T., Minneapolis, "Radiographing of Kidneys"; Gertrude Johnson, R.T., Altoona, Penn., "Do You Know?" Glenn W. Files, R.T., Chicago, "Radiographing of Chest"; Virginia H. Eller, R.T., Janesville, Wis., "Heart Graphing as Duty of Technician—Its Technic"; W. W. Pollino, R.T., Brooklyn, N. Y., "Fast Exposure in Teleoroentgenography"; Harold G. Petsing, R.T., Chicago, "Prevailing Opinions Regarding Radiography of Chest"; H. A. Tuttle, R.T., Chicago, "Some Thoughts on Radiography"; Anna R. Bolin, Chicago, "Roentgenological Research in Natural History"; Gentz Perry, M.D., Evanston, Ill., "Ethics"; M. T. MacEachern, M.D., Chicago, "Planning, Organization, and Management of X-ray

Department in Hospital"; Chester H. Warfield, M.D., Chicago, "Routine Work in Large X-ray Department"; George M. Landau, M.D., Chicago, "To Whom may X-ray Films be Shown?" Jerome R. Head, M.D., Chicago, "Technic and Procedure in Using Lipiodol and Raying of Chest"; Henry Schmitz, M.D., Chicago, "Progress in Radiation Treatment of Uterine Cancer"; Hans A. Jarre, M.D., Detroit, "Cinex Camera—Its Value to Busy Roentgenologic Laboratory"; William E. Redlick, D.D.S., Chicago, "Simplified Dental Radiographic Technic"; L. P. Kuhn, M.D., Chicago, "Myositis Ossificans Traumatica—Special Considerations for Technicians"; Mabel Walsh, R.T., Chicago, "Routine Technic in Demonstrating Gall-bladder Function after Administration of Dye"; H. N. Beets, Chicago, "Commonsense Radiography."

The first issue of *The X-Ray Technician* appeared in July, 1929, and met with an enthusiastic reception by X-ray technicians and the medical profession all over the world. There are at present eighty subscriptions from London alone.

The following officers were elected for the coming year:

President, Mrs. E. C. Grierson, R.T., 1476 Selby Ave., St. Paul, Minn.; *First Vice-president* and *President-elect*, Miss Margaret Hoing, R.T., 2561 North Clark St., Chicago; *Second Vice-president*, Miss Emma L. Stewart, R.T., 829 Starks Bldg., Louisville, Ky.; *Third Vice-president*, Sister Mary Artos, R.T., Sacred Heart Sanatorium, Milwaukee, Wis.; *Secretary-Treasurer*, Mary E. Bell, R.T., New Asbury Hospital, Minneapolis, Minn.; *Executive Committee:* H. A. Tuttle, R.T., Chicago, F. A. Senechal, R.T., St. Louis, C. J. Bodle, R.T., Winnipeg, Man., Canada.

Mr. E. C. Jerman has been elected President Emeritus of the American Society of Radiographers.

St. Paul, Minnesota, was chosen as the meeting place for the annual convention in May, 1931, the time of the month to be decided upon at a later date by the Executive Committee in order to avoid conflict with medical meetings.

MARY E. BELL, *Secretary-Treasurer.*

QUESTIONNAIRE CONCERNING THE TRIP TO PARIS NEXT SUMMER

At the suggestion of I. Seth Hirsch, M.D., the following questionnaire is presented to the attention of all readers in North America, who would naturally sail from New York. It has to do with plans for travelling in a group, at materially reduced rates, to the Third International Congress on Radiology, scheduled to meet in Paris July 27 to 31, 1931. It will readily be seen that to reply to the questionnaire as promptly as possible is a constructive step in the formation of coherent plans to get the very most out of the trip to the Continent.

If interested, please write to Dr. I. Seth Hirsch, 136 East 64th Street, New York City, letting your letter take the form of a reply to the following questions:

1. Do you intend to be present at the Third International Congress on Radiology in Paris in 1931?

2. Will you be accompanied by members of your family?

3. Would you prefer to sail so as to arrive two weeks in advance of the meeting?

4. Would you prefer to sail so as to arrive a few days before the meeting?

5. When do you intend to return?

A very low rate can be obtained from a trans-Atlantic line for a one-cabin ship. The rates can be made particularly low if those attending come back as a group.

SECTION ON RADIOLOGY
AMERICAN MEDICAL ASSOCIATION

JUNE 25, 26, 27, 1930

Chairman's Address.
FRED M. HODGES, M.D., Richmond, Va.
Radium in Benign Lesions of the Skin.
FRANK E. SIMPSON, M.D., Chicago, Ill.
Discussion to be opened by E. H. SKINNER, M.D., Kansas City, Mo.
X-ray in the Treatment of Infections.
A. U. DESJARDINS, M.D., Rochester, Minn.
Discussion to be opened by ROLLIN H. STEVENS, M.D., Detroit, Mich.
Irradiation of Mammary Cancer, with Special Reference to Measured Tissue Dosage.
BURTON J. LEE, M.D., and GEORGE T. PACK, M.D., New York, N. Y. (By Invitation.)
Discussion to be opened by HENRY J. ULLMANN, M.D., Santa Barbara, Calif.
Cancer of the Mouth—Its Prevention and Cure.
GEORGE E. PFAHLER, M.D., and JACOB H. VASTINE, M.D., Philadelphia, Pa.
Discussion to be opened by GEORGE W. GRIER, M.D., Pittsburgh, Pa.
Indications and Limitations for Intensive Roentgen-ray and Radium Treatment of Advanced Cancer.
BERNARD P. WIDMANN, M.D., Philadelphia, Pa.
Discussion to be opened by ALBERT SOILAND, M.D., Los Angeles, Calif., and FRANCIS CARTER WOOD, M.D., New York, N. Y.
Comments on Cancer Treatment.
ALBERT SOILAND, M.D., Los Angeles, Calif.
Discussion to be opened by DOUGLAS QUICK, M.D., New York, N. Y.
Lymphomalignum (Hodgkin's) and Lymphosarcoma: Pathogenesis, Radiotherapy and Prognosis.
ISAAC LEVIN, M.D., New York, N. Y.
Semilunar Malacia.
E. S. BLAINE, M.D., Chicago, Ill.
Discussion to be opened by CARROLL E. COOK, M.D., Chicago, Ill., and HOWARD P. DOUB, M.D., Detroit, Mich.
Roentgenographic Studies in Normal Osseous Development.

E. K. SHELTON, JR., M.D., Santa Barbara, Calif.
Discussion to be opened by BUNDY ALLEN, M.D., Tampa, Fla.
Encephalography and Ventriculography: Their Indications and Contra-indications.
EUGENE P. PENDERGRASS, M.D., Philadelphia, Pa.
Discussion to be opened by TEMPLE FAY, M.D., Philadelphia, Pa.
Intravenous Urography (Swick Method).
LEOPOLD JACHES, M.D., New York, N. Y.
Cholecystography: An Analysis after Six Years' Application.
SHERWOOD MOORE, M.D., St. Louis, Mo.
Discussion to be opened by JAMES T. CASE, M.D., Chicago, Ill.
Roentgen Diagnosis of Ascariasis.
VINCENT W. ARCHER, M.D., University, Va.
Discussion to be opened by EUGENE P. PENDERGRASS, M.D., Philadelphia, Pa.
Hyperplastic Tuberculosis of the Duodenum and Terminal Ileum.
JOHN DAY GARVIN, M.D., Pittsburgh, Pa.
Discussion to be opened by LAWRENCE REYNOLDS, M.D., Detroit, Mich.
A Roentgenological Study of the Chest in Rachitic Children.
RALPH S. BROMER, M.D., Philadelphia, Pa.
Discussion to be opened by WILLIAM A. EVANS, M.D., Detroit, Mich.
Roentgenologic Diagnosis of Diaphragmatic Hernia.
A. B. MOORE, M.D., and B. R. KIRKLIN, M.D., Rochester, Minn.
Discussion to be opened by E. L. JENKINSON, M.D., Chicago, Ill.
Correlation of X-ray Measurements of the Heart with Clinical Condition of the Patient.
SINCLAIR LUTON, M.D., St. Louis, Mo.
Discussion to be opened by HAROLD E. B. PARDEE, M.D., and LEON T. LE WALD, M.D., New York, N. Y.
Spontaneous Pneumothorax.
ROBERT B. TAFT, M.D., Charleston, S. C.
Discussion to be opened by JOHN M. BARNES, M.D., Ann Arbor, Mich.
The Roentgen Diagnosis of Small Pleural Effusions, with Observations of the Movement of Pleural Effusions.

Leo G. Rigler, M.D., Minneapolis, Minn.

Discussion to be opened by L. R. Sante, M.D., St. Louis, Mo.

FIFTEENTH ANNUAL CLINICAL SESSION OF THE AMERICAN COLLEGE OF PHYSICIANS

The American College of Physicians will hold its Fifteenth Annual Clinical Session at Baltimore, Maryland, from March 23 to 27, inclusive, 1931. The Lord Baltimore Hotel will be headquarters.

Dr. Sydney R. Miller, of Baltimore, as President, will have charge of the selection of the general scientific program. Dr. Maurice C. Pincoffs, of Baltimore, has been appointed by the Board of Regents as the General Chairman of the Session, and will have charge of all local arrangements, including the making up of the program of clinics. Business details will be handled by the Executive Secretary, Mr. E. R. Loveland, from the College headquarters, 133-135 S. 36th Street, Philadelphia, Pa.

The attention of secretaries of various societies is called to the above dates, in the hope that their societies will select non-conflicting dates for their 1931 meetings.

A POST-GRADUATE WEEK OF PHYSICAL THERAPY

To be Conducted by the American Congress of Physical Therapy

Announcement is made of "A Post-graduate Week of Physical Therapy" in conjunction with the ninth annual scientific session of the American Congress of Physical Therapy, to be conducted September 8 to 12, inclusive, 1930, at the New Hotel Jefferson, St. Louis, Mo.

An intensive post-graduate week of physical therapy is promised. Elaborate plans have been perfected for teaching, demonstrations, and clinics. The physician who is interested in physical therapeutics and who has not had any instruction in the work will find the lectures on the fundamentals a sound basic means for further study. The more experienced, on the other hand, will gain considerably from the advanced expositions on light, heat, electricity, massage and all the other physical agents utilized in practice. Every phase of physical therapy will be covered. The subjects will be general and specific and so varied as to appeal to both the general practitioner and the specialist.

While it is appreciated that a week is a rather short period for post-graduate teaching, the systematic arrangement of the program makes it possible for the physician to attend only those sessions in which he is vitally interested. As has been the practice in the past, sectional gatherings will prevail in medicine, surgery, and eye, ear, nose and throat. Several of the afternoons and evenings will be given over to addresses by prominent guests. There will be symposia on "Education and Teaching of Physical Therapeutics" and on "The Relation of the Physician and the Technician in Office and Hospital Practice."

New features in the conduct of clinics and demonstrations will be observed. In fact, so many new features have been arranged that they cannot be enumerated here. The preliminary program will be issued within a short time. Full information and details are contained in it. Send your name and address to the Executive Secretary, American Congress of Physical Therapy, Suite 716, 30 N. Michigan Avenue, Chicago, Ill.

THE JOHN PHILLIPS MEMORIAL PRIZE

The American College of Physicians announces the John Phillips Memorial Prize

of $1,500, to be awarded for the most meritorious contribution in internal medicine and sciences contributing thereto, under the following conditions:

(1)   The contribution must be submitted in the form of a thesis or dissertation based upon published or unpublished original work.

(2)   It must be mailed to the Executive Secretary of the American College of Physicians on or before August 31, 1930.

(3)   The thesis or dissertation must be in the English language, in triplicate, in typewritten or printed form, and the work upon which it is based must have been done in whole or in part in the United States or Canada.

(4)   The recipient of the prize would be expected to read the essay at the next Annual Meeting of the College, after which he would be officially presented with the prize by the President.

(5)   The College reserves the right to make no award of the prize if a sufficiently meritorious piece of work has not been received.

(6)   The announcement of the prize winner will be made not later than two months before the Annual Meeting.

AMERICAN COLLEGE OF PHYSICIANS,
E. R. LOVELAND, *Executive Secretary*,
133-135 S. 36th Street,
Philadelphia, Pa.

BOOK REVIEWS

LA SENSITOMÉTRIE CUTANÉE. By J. SAIDMAN, Directeur-Fondateur de l'Institut d'Actinologie. Published by Gaston Doin et Cie, Editeurs, 8, Place de l'Odéon, Paris, 1930. Pages 294. Price 60 francs.

In the first section of this monograph Saidman discusses the use of his automatic sensitometer in establishing doses of actino-therapy so that a rational posology can be developed, and he points out that there are many variations in skin sensitivity. By his sensitometer the reactivity of the patient to the radiation with which he is to be treated is determined, so that all empiricism in treatment can be avoided. There follows in the second section the clinical applications of these sensitivity tests. A bibliography completes the book.

This monograph is of importance to whoever is doing specific actinotherapy.

ROENTGENOGRAPHIC TECHNIQUE: A MANUAL FOR PHYSICIANS, STUDENTS, AND TECHNICIANS. By D. A. RHINEHART, A.M., M.D., Professor of Roentgenology and Applied Anatomy, School of Medicine, University of Arkansas; Roentgenologist to St. Vincent's Infirmary, Baptist State Hospital, Missouri Pacific Hospital, and the Arkansas Children's Hospital. Published by Lea & Febiger, Philadelphia, 1930. Pp. 388. Price $5.50.

In writing this book the author has particularly kept in mind the needs of medical students in classes in roentgenology, roentgen-ray technicians, and physicians either undertaking roentgen-ray work for the first time or doing roentgenography for themselves and their colleagues.

The usual chapters on elementary electricity, X-ray physics, and roentgen-ray machines are written in a concise, practical fashion that will be appreciated by those seeking a general review of such subjects.

The author has endeavored to standardize the technic of roentgenographic exposures, and several experiments are described which enable the operator to calibrate his own machine and apply the author's technic. These experiments will also serve to impress students with the various factors concerned in X-ray exposures and the effects obtained by varying each.

That portion devoted to positions for ex-

posure is quite complete. The various technics described by numerous roentgenologists are discussed in detail, and all the standard positions are illustrated by excellent photographs alongside of which the resulting roentgenograms are reproduced. The concise anatomical description preceding the technic for each part or organ is especially *apropos* and will be helpful to non-medical operators.

This book is a distinct addition to the roentgenologic literature and fulfils the author's purpose in a most commendable manner.

PEPTIC ULCER. ANNALS OF ROENTGEN-OLOGY, VOLUME TEN. By JACOB BUCKSTEIN, M.D., Instructor in Gastro-intestinal Roentgenology, Cornell University Medical College; Alimentary Tract Division, Roentgen Department, Bellevue and Beth Israel Hospitals; Consultant in Gastro-enterology, U. S. Veterans Bureau, Central Islip and Rockaway Beach Hospitals; Associate Attending Gastro-enterologist, Sydenham Hospital. Introduction by HAROLD E. SANTEE, M.D., Clinical Professor of Surgery, Cornell University Medical College; Director of Surgery, Bellevue Hospital (Cornell Division). Published by Paul B. Hoeber, Inc., New York, 1930. Pages 337. Price $12.00.

The scope of this book is practically confined to gastric, duodenal, gastrojejunal, and jejunal ulcer. It is a clinical roentgenological study of 240 cases, with case histories, and contains 287 illustrations. It is divided into four sections:

I. Introduction, which deals with the early history of gastro-intestinal examinations, barium meals, stomach types, peristalsis, relation of stomach type to physical habitus, etc.

II. Gastric ulcer, including a discussion of roentgenological contributions to this subject, with a description of organic deformities, effect of ulcer on motility, relation of benign to malignant ulcer, pathology of ulcer in relation to localization, greater curvature ulcers, healing of ulcer, and technic of examination.

III. Duodenal ulcer, with a consideration of the duodenal bulb, development of roentgenology of duodenal ulcer, and technic of examination.

IV. Gastrojejunal and jejunal ulcer, with a consideration of the ulcer niche, deformity, localization of tender points, etc.

There is a serious doubt as to the pictorial quality of the original films, yet withal the book is worth adding to one's library.

ACTA RADIOLOGICA. *Supplement III, Part 1.* A report of the Second International Congress of Radiology and the proceedings of the Joint Scientific Meetings of the Congress, Stockholm, July 23 to 27, 1928. *Supplement III, Part 2.* Abstracts of communications at the Second International Congress of Radiology. *Supplement IV, Teaching and Training in Medical Radiology.* Papers delivered at Second International Congress of Radiology.

These supplements to *Acta Radiologica* report in detail the various proceedings of the Second International Congress of Radiology. Excellent reports covering these will be found in RADIOLOGY, October, 1928, XI, 347–352.

ABSTRACTS OF CURRENT LITERATURE

AUTHOR INDEX

SUBJECT INDEX

APPENDIX (DIAGNOSIS)

Radiological Diagnosis of the Diseased Appendix. A. Orliansky. Brit. Med. Jour., Feb. 22, 1930, No. 3607, p. 330.

The appendix can be visualized radiologically in about 90 per cent of cases. Frequently it is visualized only after thorough purgation of the bowels. Two different types of fixed appendix are described: (*a*) The appendix fixed to the cecal wall; stretching of the fixed appendix through filling of the cecum causes pain; the pain subsides when the cecum empties. (*b*) The appendix with the tip only fixed to the pelvic wall; emptying, with consequent rise of the cecum, causes pain through dragging on the fixed appendix.

Spasticity of the cecum may be observed during an attack of acute appendicitis, but occasionally also in chronic disease. The dilated appendicular canal, and particularly the club-like dilatation of the distal end of the appendix, are almost certain signs of a diseased appendix.

Not much importance can be attached to tenderness of the visualized appendix in the absence of other confirmatory signs and symptoms of appendicular disease. Cecal stasis may be due to a chronic appendicitis, but, on the other hand, may be found in cases of normal appendix. In the presence of cecal stasis and chronic appendicitis, it is difficult to say which of the two is the primary, and which the secondary condition.

Appendicular stasis is suggestive of chronic appendicitis only in the presence of other confirmatory radiological signs and clinical symptoms of appendicitis. Stasis persisting after the administration of a purgative is sometimes caused by a partial, localized stenosis of the appendicular canal; the fluid barium penetrates through the narrowed lumen, but cannot be expelled after it has thickened and hardened through absorption of fluid. Appendicular stasis is sometimes seen in chronic tubo-ovarian inflammatory conditions, with or without inflammatory involvement of the appendix. The non-filling of the appendix can be interpreted as a pathological sign only in cases in which the appendix cannot be visualized after repeated purgation, each purgation being followed by a barium meal.

WALLACE D. MACKENZIE, M.D.

Roentgenographic Visualization of Appendical Perforation. José Arias Avellán. Am. Jour. Surg., February, 1930, VIII, 427.

The author reports a case with indefinite abdominal symptoms, yet giving no signs or symptoms pointing definitely to pathology in the appendix. During the course of the injection of a barium enema, the appendix was found to be large and retrocecal. When it was entirely filled, the barium was seen to escape from the distal end and to pass into the abdominal cavity. The reproductions of several films are published with this paper, graphically showing this phenomenon. Under appropriate treatment the patient recovered completely.

HOWARD P. DOUB, M.D.

BONE (DIAGNOSIS)

Radioulnar Synostosis, with Report of a Case. Edward S. Blaine. Ill. Med. Jour., March, 1930, LVII, 166.

The condition of radioulnar synostosis, or "congenital pronation," is of considerable interest. About a hundred cases have been reported in the literature.

This condition is due to a congenital fault and consists in the fusion of the upper portions of radius and ulna in a position of more or less pronation so that supination is not possible. The amount of fusion in reported cases is from one to six centimeters in length. It is a bilateral condition in about 50 per cent of the cases and occurs more frequently in males than in females. In several cases it occurred in successive generations of the family.

The X-ray report of Dr. Blaine's case is as follows: "The X-ray examination reveals a bony fusion of the radius with the ulna. The synostosis is one centimeter in length on the

left side and six centimeters on the right side. The bone texture is normal. There is asymmetry at the wrists, the right one showing a degree of posterior luxation of the ulna with a prominent styloid process. The left wrist is normal. No other bone or joint changes were found."

The writer discusses the various types and considers the embryological and phylogenetic aspects of this type of synostosis.

C. H. DeWitt, M.D.

Fractures of the Hip. C. E. Ruth and V. A. Ruth. Jour. Am. Med. Assn., Jan. 18, 1930, XCIV, 169.

At the hospital the primary diagnosis of fracture of the hip should be made with the X-ray, the film giving an accurate picture of the condition. Proper methods can be instituted to obtain and maintain reduction. Frequent checks on the position should be made with the X-ray. The authors consider fractures under six heads, roughly, in the order of their interest and difficulty of treatment. They stress the value of the X-ray in the primary diagnosis and in the subsequent treatment.

C. G. Sutherland, M.B. (Tor.)

Roentgenologically Demonstrable Deformities of the Patella Following Fracture. M. J. Madlener and H. R. Paas. Fortschr. a. d. Geb. d. Röntgenstr., January, 1930, XLI, 38.

On re-examination of thirty-one healed patellar fractures, deformities were studied which occurred as a result of traumatism, but did not belong to the arthritis deformans entity. A number of these fractures had been treated by wire sutures, and some of them conservatively without surgical interference. On roentgenologic examination in three planes, sagittally, frontally, and axially, deformities in all diameters were observed. Elongation was most common and most pronounced; broadening was not infrequent, but not so marked as elongation. Irregularities of all

surfaces were quite common, partly as a result of callus formation, partly as the result of exostoses which may have occurred either following displacement of particles of periosteum, or as calcifications and bone formation in adjacent soft tissues, especially tendons and ligaments, finally becoming fused to the bone itself. Possibly the wire suture was partly responsible for some of the deformities, but it was also remarkable that the functional result practically never was impaired by the degree of patellar deformity.

H. A. Jarre, M.D.

Concerning the So-called "Osteitis Fibrosa" ("Osteodystrophia Fibrosa"). R. Kienböck. Fortschr. a. d. Geb. d. Röntgenstr., January, 1930, XLI, 34.

This short paper is a consideration of two disease entities: First, osteitis deformans Paget; second, osteitis fibrosa cystica generalisata, Engel-Recklinghausen or "generalized fibrocystic disease of the bones." Kienböck states that there is no relationship between these two disease entities, and that they can be clearly separated anatomically, as well as clinically and roentgenologically. Osteitis deformans Paget is a peculiar benign atrophic-hypertrophic dysplasia which, according to anatomic symptoms, may also be termed a sclerotic-hyperostotic osteoporosis with a complete metaplasia of the involved portions of bone. In this disease resorption and regeneration of osseous tissue are closely associated. The bones appear thickened and their normal curvatures are increased. Their surfaces appear somewhat loosened up and a new shell of apposition of bone may be seen. Fibrotic osteoid tissue may be interspersed. The affected portions of the skeleton are usually diffusely and evenly diseased. No hemorrhagic cysts occur, but occasionally there are atrophic cysts. Fractures occur but rarely, and most frequently are fissures or green-stick fractures with delayed healing and formation of large intramuscular "osteomata." Clinical symptoms are rather insignificant, considering the extent of the skeletal disease. The course

is slowly progressive though occasionally involvement of only one bone occurs. The cranium is frequently affected. Large portions of the skeleton may become involved, but always some bones remain healthy; thus the disease process may be multiple, but it never is generalized. The onset of the disease usually occurs around the fortieth year, never during adolescent age. Secondary malignant degeneration of Paget's disease was observed by Paget himself.

Osteitis fibrosa cystica generalisata also is a benign skeletal affection of exquisitely atrophic dysplasia. First, a very marked decalcification or osteoporosis occurs, with but very little regeneration of supporting new bone tissue. Much fibrotic and osteoid tissue develops, leading to a systematic fibrosis and malacia of the bone. The entire skeleton is diffusely affected. It is a generalized disease. The bones become abnormally weak and brittle, resulting, therefore, in extensive deformities and frequent fractures, with large hematomata and hemorrhagic cysts, so-called "brown tumors." As a whole, the changes show a great variety and irregularity. Clinical symptoms usually start with deformities, fractures, spontaneous ruptures. The persons affected suffer severe pain, especially under the influence of multiple fractures. Very soon they become complete invalids. In all severe cases tumor formation of the thyroid gland, arising from the epithelial bodies, takes place. Progressive and regressive stages occur quite frequently. Complete cure has been observed occasionally, resulting in relief of pain, with remaining deformities of the skeleton. The onset of the disease may occur at any age, including youth and adolescence. The female sex is commonly affected. Kienböck states that differentiation between these two disease entities is important, as therapeutic indications depend upon a correct diagnosis.

H. A. JARRE, M.D.

CHEST (DIAGNOSIS)

Calcification of the Pleura. K. Ulrich. Röntgenpraxis, March 1, 1930, II, 212.

Calcification of a thickened pleura can be shown roentgenologically fairly often. In about 1,800 chest examinations made by the author, pleural thickening and adhesions were found in 24.6 per cent. In 3.5 per cent of the latter group, calcification was demonstrable. Fluoroscopic examination alone often does not show this condition. A plate-like calcification is most frequently encountered, less so the disseminated and irregular type. Pleurisy leading to thickening and calcification dated back more than ten years in 11 of the 16 cases, the shortest time being five years. A rather long period is necessary for pleural calcification, in the author's opinion. In only one case could tuberculosis be held responsible for it. A hematothorax after injuries seemed to be the etiological factor in many instances.

H. W. HEFKE, M.D.

Chest Roentgenograms of Non-tuberculous Children Suspected of being Tuberculous. Ernst Wolff and Robert S. Stone. Jour. Am. Med. Assn., Feb. 15, 1930, XCIV, 458.

The marked confusion existing in the interpretation of the shadows in the roentgenograms of children's chests is remarked by Wolff and Stone. Twenty normal children were examined at the Institute of Child Study in Berkeley, California, as a control, and comparisons of the findings in the normal and the group studied were charted. The authors' conclusions were that a diagnosis of mediastinal glands or lung tissue cannot be based on these observations. No definite correlation was found to exist between the positive roentgen observations and the clinical history.

C. G. SUTHERLAND, M.B. (Tor.)

Roentgen Study of Apical Chest Tumors. W. F. Henderson. Am. Jour. Surg., February, 1930, VIII, 414.

These tumors are uniformly located in the apex of the chest. They have no connection with the hilum and are not of mediastinal origin, but apparently are primary endotheliomata of the pleura. They are characterized

by a lower border, very sharp and usually almost perfectly straight, with little or no tendency to invade the subjacent lung tissue, and present a picture of uniform density. The remaining portions of both lungs are usually clear. A diffuse thickening of the pleura from a previous inflammatory process might cause confusion, but usually other pleural changes make the differentiation possible. Clinically, there is severe pain in the shoulders, radiating down the arm, and there is a surprising disproportion between the magnitude of the roentgen findings and such physical signs as can be elicited. The lack of physical findings is one of the striking features in this disease and many cases are entirely unsuspected clinically. In several patients, shortly before death, the tumor exhibited a tendency to break through the lower margin and to involve the structures immediately beneath. In these cases, no evidence of any metastases elsewhere could be demonstrated. In one case, however, metastatic lesions did occur. Ewing describes these tumors as "originating in the form of multiple nodules or flat elevations, widely distributed over either the parietal or visceral pleura, or perhaps both. These nodules or plaques fuse to form a dense firm mass which covers and compresses the lung. A serofibrinous or bloody exudate accompanies the growth, which gathers in small cysts or larger collections."

Contrary to the findings of Pancoast, the author observed little or no ocular symptoms, and also his cases have been almost uniformly attended with hoarseness, advanced in certain cases to the degree of aphonia. He has seen eight cases, of which seven were in adults. All of these patients but one were of the male sex. Three case reports are presented.

HOWARD P. DOUB, M.D.

An Unusual Case of Massive Atelectasis of the Right Lung. Harry L. Baum. Laryngoscope, February, 1930, XL, 124.

The author reports a very interesting case of massive atelectasis of the right lung, in which the patient was ambulant, had no temperature, slight shortness of breath, pulse of about 100, and felt better generally than she did before the collapse occurred. X-ray films taken six months before the collapse showed evidence of slight tuberculous activity in both upper lobes. There was a history of pneumonia at the age of ten. An X-ray film taken after the collapse showed typical findings of massive atelectasis, with displacement of the heart and mediastinal structures, with over-expansion of the left lung. Bronchoscopically, stenosis of the right main bronchus was observed, starting just below the carina. About a dram of mucopurulent secretion (positive for tubercle bacilli, but not in large numbers) was aspirated. The Wassermann test was negative. There was no history of foreign body. Six months later the atelectasis was still present and the condition of the patient was unchanged.

B. C. CUSHWAY, M.D.

Comparative Findings of Roentgen Examination of the Lungs, and Autopsy. Erich Saupe. Röntgenpraxis, March 1, 1930, II, 193.

Close co-operation between pathologist, roentgenologist, and clinician allowed the author to compare roentgenograms of the chest with the autopsy findings. The roentgenologist should hesitate to make too definite statements about the type of tuberculosis, whether productive or exudative. Even the pathologist can often decide it only with the microscope. Soft shadows in the apices do not always indicate an active process; they often represent small atelectatic-cirrhotic areas, or small pleural plaques. The roentgenological demonstration of a thin interlobar shadow must not necessarily mean an interlobar pleurisy. A normal interlobar pleura may be shown, if the conditions are correct. A localized emphysema of the lung may occasionally make it difficult to diagnose cavities, some of the emphysematous blebs reaching the size of a cherry. Bronchiectases were found more often during autopsy than in the roentgen films. Their diagnosis is not made frequently enough by the radiologist in the author's opinion. Bronchography may be of help in doubtful cases.

The roentgen picture of chronic passive congestion, although typical in many instances, may sometimes be very confusing. Complicating bronchopneumonia or multiple small infarcts are often overlooked. Small bronchial carcinomas are very hard to demonstrate, and sometimes only bronchography will show them. The signs of bronchostenosis can be elicited occasionally by forced and fast inspiration. One must remember that some chronic pneumonia accompanies all cases of bronchus and lung carcinoma. Very small lung tumors, often invisible themselves, may present very large mediastinal metastases, which, however, are usually unilateral, in distinction from the primary mediastinal tumors. A trial of radiotherapy may be the only means of making a differential diagnosis. It is very difficult to find carcinomatous involvement of the pleura. Tangential examination in different levels is often necessary. Many other chest conditions are described, comparing the findings of the roentgen examination with the autopsy, and especially pointing out the possibilities of error and the difficulties of differential diagnosis.

H. W. HEFKE, M.D.

Atelectatic Bronchiectasis. A. J. Scott Pinchin and H. V. Morlock. Brit. Med. Jour., Jan. 4, 1930, No. 3600, p. 12.

The authors present cases showing, clinically, a cough and the raising of much sputum; and radiologically, a triangular shadow at the base of the lung, one side of which rests on the diaphragm and one along the mediastinum. They concur with the work of Singer and Graham in demonstrating bronchiectasis in these cases by the injection of lipiodol. The shadow of an atelectatic lobe or part of a lobe may be similar to the triangular shadow now under discussion. The clearing up of a collapsed area of lung is dependent on the free mobility of the chest and diaphragm, and occurs least readily in the location under discussion.

It is concluded that the most common lesion with which this shadow is associated, is bronchiectasis. It is agreed with Wallgreen and Sergent that the presence of this shadow

should always raise the suspicion of a bronchiectasis unless other clinical evidence is forthcoming to clinch the diagnosis of a mediastinal effusion. It is a matter for speculation how much influence local areas of collapse exert in the etiology of bronchiectasis.

WALLACE D. MACKENZIE, M.D.

GALL BLADDER
(NORMAL AND PATHOLOGICAL)

The X-ray in the Differential Diagnosis of Bile Tract Disease. D. S. Beilin. Ill. Med. Jour., January, 1930, LVII, 45.

In examining the gall bladder following dye administration, we should remember that: "The gall bladder, liver, duodenum, stomach, and pancreas are embryologically, anatomically, physiologically, and pathologically closely related" (MacCarty). In addition to the findings possible from cholecystography, in which the author prefers the oral method, a roentgenological examination can throw some light on several other conditions. Abnormalities in size, position, and form of the liver, abscess of the liver, sub-diaphragmatic abscess, cancer of the liver, and syphilis of the liver often give fairly characteristic findings. Carcinoma of the stomach and head of the pancreas should always be considered in bile tract disease. In selected cases, pneumoperitoneum has a definite place.

W. W. WATKINS, M.D.

The Graham Test. Edward L. Young, Jr. New Eng. Jour. Med., Jan. 30, 1930, CCII, 219.

Two years ago this author reported end-results in a series of cases of cholecystitis, which showed 63 per cent cured by operation. The present study was made to ascertain whether the use of the Graham test has helped the accuracy of diagnosis. The study includes 144 cases, 84 of which were operated upon. Of the positive diagnoses based on the dye test, 88 per cent were correct for bile tract disease. Where the test was negative, 68 per cent were correct. The figures seem to show a considerable chance for error in the Graham test, which we must always remember is a test

for function; therefore, the clinical evidence should always take precedence. The use of the test increases the accuracy of the diagnosis.

W. W. WATKINS, M.D.

Oral Cholecystography in the Study of the Digestive Tract. **Arrigo Foà. Minerva Med., Dec. 8, 1929, IX, Pt. 2, p. 909.**

Systematic researches on one hundred cases of normal individuals and in morbid conditions of the gall bladder have convinced the author that cholecystography by the oral method involves so few sources of error that its routine use is indicated. Cholecystography by the intravenous method is advised only in the few cases in which, without apparent pathological cause, the oral method does not succeed.

L. MARINELLI.

GASTRO-INTESTINAL TRACT (DIAGNOSIS)

Diverticulitis, with Particular Reference to its Diagnosis by Radiology. **W. H. Rowden. Brit. Med. Jour., March 1, 1930, No. 3608, p. 381.**

The first step toward diverticulitis is the development of a condition of diverticulosis. That diverticulosis is not a congenital abnormality is concluded from the rarity with which the condition is found in young persons. The condition of diverticulosis itself is not a disease. It is only when inflammatory changes occur in or around the diverticula that symptoms and signs of disease are manifested.

A complete and definite diagnosis of diverticulitis can be made only by means of exploratory laparotomy and microscopical examination of an excised portion of the affected bowel, or by means of X-ray examination. As the treatment is chiefly medical, X-ray examination is the method of choice.

An examination by means of the opaque meal will give information as to the presence of diverticulosis, but it will not, as a general rule, provide evidence as to whether or not there is an accompanying diverticulitis. For the demonstration of diverticulitis an opaque enema is preferable. The two methods may be satisfactorily combined. It is of the utmost importance that roentgenographs should be taken with the patient in the right and left oblique positions, in addition to the usual one taken in the postero-anterior position.

The earliest change in the appearance of the bowel in diverticulitis is an alteration in the haustration. The haustral indentations, instead of being placed opposite one another, alternate on each aspect of the bowel; secondary smaller indentations also make their appearance; the indentations are regular in outline. This is the stage of irritation. In the next stage the haustral indentations, in addition to being spaced irregularly, become irregular in outline, producing an irregular V-shaped or W-shaped appearance of the bowel. This is the stage of thickening of the bowel wall. The third stage is that of the filling defect. The filling defect is produced by encroachment upon the lumen of the bowel by the thickened wall, resulting in a narrowing, which, if the condition is untreated, will eventually lead to complete obstruction. Frequently the three stages can be seen in the same patient, involving different parts of the bowel.

With regard to the differential diagnosis, malignant disease comes first. The distinguishing points are:

1. Diverticulitis is associated with the presence of diverticula in the neighborhood of the deformity in the outline of the bowel; in carcinoma, diverticula, as a rule, are not present.

2. Diverticulitis produces a deformity which is characteristic of the disease. The deformity produced by a growth varies according to whether the growth is of the ulcerating, papillomatous, or encircling-ring type.

3. Diverticulitis usually involves a considerable length of the bowel, whereas the length of the bowel involved by carcinoma is short.

Diverticulitis is differentiated from ulcerative colitis by the fact that in the latter there

is complete loss of haustration. The possibility of double pathology must not be lost to sight.

WALLACE D. MACKENZIE, M.D.

Gastric Ulcer and Deformity of the Spine. L. Dinkin. Röntgenpraxis, January, 1930, II, 11.

Mechanical factors as caused by scoliosis of the lower dorsal and upper lumbar spine are considered to be of great importance in the etiology of some gastric ulcers. Thirty-five cases are reported, in thirty-three of which gastric ulcer, proven by fluoroscopy, was found at the level of the most prominent point of the scoliosis, while in two cases it was found at the level of the most marked depression of the costal margin. The coincidence between gastric ulcer and spinal deformity is so frequent that it is advisable to investigate the stomach for ulcer in all cases of marked deformity. Scoliosis toward the left seems in most cases to predispose to ulcer on the lesser curvature or the corpus, and scoliosis toward the right, to ulcer formation in the pyloric region.

H. W. HEFKE, M.D.

Roentgen Diagnosis of Lesions of the Jejunum and Ileum. Max Ritvo. Am. Jour. Roentgenol. and Rad. Ther., February, 1930, XXIII, 160.

The X-ray findings in lesions of the jejunum and ileum are described and illustrated. Obstruction, hypermotility, diverticula, malpositions and displacements, adhesions, tuberculosis, ulcer, neoplasms, foreign bodies, and post-operative changes are the conditions considered. Except for acute intestinal obstruction which may give characteristic X-ray signs by plain films, the barium sulphate meal is used, and its passage through the small intestine is studied at one-half to one-hour intervals from the time it first enters the jejunum until the terminal ileum is empty. Properly performed, the roentgen study of the small bowel should in most instances make for a correct differential diagnosis, where, otherwise, the

correct pre-operative diagnosis might be impossible.

J. E. HABBE, M.D.

The Rate of Passage of Inert Materials through the Digestive Tract. Frederick Hoelzel. Am. Jour. Physiol., March, 1930, XCII, 466.

The rate of passage of various inert materials through the digestive tract was studied in 16 rabbits, 7 guinea pigs, 4 dogs, 2 cats, 50 albino rats, 8 white mice, 3 pigeons, 1 hen, 1 monkey, and 1 man (the author). The test materials included cellulose (in the form of knots made of cotton thread), seeds, glass beads, pieces of rubber, aluminum, steel, silver, and gold. Rates of passage were found more or less proportional to the specific gravity of the test materials—the heavier materials passing slower than the light materials. The rates of passage also varied considerably in the different species and individuals.

During a typical period of about a month in which the human subject took a number of knots, glass beads, and marked pieces of silver and gold daily, the average rates of passage were: knots, 29.7 hours; glass beads, 47.3 hours; silver 81.1 hours, and gold, 123.5 hours. These results indicate that some delay in the passage of a small, heavy foreign body through the digestive tract is entirely normal. During a period of 296 days in which marked pieces of gold were taken daily (total, 5,589 pieces), the rates of passage of individual pieces varied from 27 hours to 528 hours and the average rate of passage of all gold taken on any day varied from 67.1 hours to 275.9 hours. Such variations occurred in spite of attempts to keep the diet and other conditions constant. Similar variations in the rate of passage of heavy materials were observed in most animals, including the monkey. The larger variations in the rate of passage of heavy material were usually independent of any corresponding variations in the passage of light material. The main sites of stasis of heavy material in man were the terminal ileum, cecum, and colon.

The rate of passage of barium sulphate was

given some consideration, particularly because it is about three times as heavy as the usual food residues. However, it became evident that the passage of a powder like barium was not directly comparable with the passage of discrete particles, such as the glass beads and other test materials used. Barium, mixed with food, tended to slow down the intestinal rate somewhat, but passed mainly along with light test material that was taken at the same time. But it is pointed out that a heavy material may also serve to speed up the rate of passage in some cases.

This study proved primarily that erroneous results were obtained by Alvarez and Freedlander when they used glass beads as a test material to determine the normal intestinal rate in man. The true rate is more correctly reflected by the faster passage of lighter test materials, such as charcoal or knots made of colored thread or string.

GRENZ RAYS (THERAPY)

Our Results with Bucky's Grenz Rays in Dermatology. Josef K o n r a d. Strahlentherapie, 1930, XXXV, 567.

The author reports the results obtained in over four hundred cases of skin diseases which were treated by roentgen rays of long wave length (10 K.V., 10 ma., 10 cm. F.S.D.). Tables are given showing the half value layer of the radiation in Cellon and also demonstrating the fact that the output of different tubes varies considerably. This makes the measurement of the dose for each apparatus and tube imperative. Emphasis is laid on the fact that for this type of therapy, as well as for therapy with the usual roentgen rays, the smallest dose necessary for the response of the lesions should be administered. The author used from 300 to 2,000 r and only rarely exceeded this latter dose up to 3,000 r. The interval between two treatments amounted to from 10 to 14 days for doses up to 800 r, 3 to 4 weeks for doses up to 1,500 r, and 4 to 6 weeks for higher doses. An erythema was observed after two or three days following the

application of 500 to 800 r. Sometimes it appeared after from 15 to 20 hours. Higher doses of from 100 to 2,000 r produced an intense reddening, slight swelling of the skin, with exudation in the irradiated area; epilation was not observed. One case developed telangiectasis after a single dose of from 4,500 r to 6,000 r. There are several similar cases now reported in the literature; also alopecia of the scalp, and atrophy, with epilation of the upper lip. Satisfactory results were obtained in cases of psoriasis, sycosis, certain types of acne, alopecia areata, verruca, tuberculosis verrucosa cutis, erythema induratum, and certain nevi. Acne rosacea, acne vulgaris, pruritus, perniones, keloid, scleroderma, atrophia cutis idiopathica, granuloma annulare, urticaria, and pemphigus did not respond well.

E. A. POHLE, M.D., PH.D.

Late Reactions Following Grenz Ray Treatment. Mario Monacelli. Strahlentherapie, 1930, XXXV, 581.

The author relates the history of three cases showing late reactions (telangiectasis, atrophy) which developed following exposure to Grenz rays. He concludes that while he does not wish to detract from the therapeutic value of Grenz rays, it is essential for one to observe the same precautions in their use as for ordinary roentgen rays.

E. A. POHLE, M.D., PH.D.

Practical Conclusions as to the Nature and Behavior of Grenz Rays (Bucky). B. Spiethoff. Am. Jour. Surg., February, 1930, VIII, 421.

In most of his treatments, the author recommends the use of 9 K.V., and only in special cases, such as simple sycosis, skin cancer, or epithelioma, or in general irradiation, does he use 11 K.V. The dosage is determined by means of Küstner's dosimeter in terms of r-units. Dosages vary from 70 to 11,000 r. The tube skin distance is from 2 to 70 millimeters. The size of the field irradiated varies directly with the distance and has a diameter of from

20 to 70 mm. with his technic. He recommends that the Grenz-ray therapeutist, like others, master the technic and physics of this method, and not be careless because the danger is less. He believes that general therapy has great value, just as has local treatment. A profound effect is exerted on the entire organism, the vegetative system, and the ductless glands alone and in combination. The general reactions are indicated by loss of appetite, weariness, and exhaustion. The local reaction is cutaneous through increase of the pathological process. As secondary effects, he often observed regulation of formerly somewhat irregular menses, general increase of vitality of the individual indicating a profound constitutional effect.

He then follows with the special indications in skin diseases, giving the dosage required in all of the various skin diseases which are amenable to this form of treatment.

HOWARD P. DOUB, M.D.

Determination of the Size of Fields in Borderline Ray Therapy. R. Spiethoff and Heinz Berger. Strahlentherapie, 1930, XXXV, 90.

The surface intensity of radiation emitted by a low voltage tube (9 K.V., 10 ma.) was determined for 2.5, 5, and 10 cm. F.S.D. A simple method is described which permits the determination of a number of fields necessary for the homogeneous exposure of certain skin areas. The article is well illustrated, demonstrating the procedure.

E. A. POHLE, M.D., PH.D.

General Considerations in Borderline-ray Therapy. G. Schulte. Strahlentherapie, 1929, XXXIV, 403.

Experience with Borderline Rays in Skin Diseases. Willy Gertz. Strahlentherapie, 1929, XXXIV, 406.

In the first of these two articles, the present status of borderline-ray therapy is briefly discussed. The author believes that in certain cases it is a welcome addition to our therapeu-

tic agents. On the other hand, this type of therapy will not replace the usual roentgen rays.

Gertz states that the output of the apparatus and tubes must be checked carefully. A potential of 10 K.V. has proved, in his experience, to be sufficient for all treatment purposes. He found that different tubes vary as much as 40, 57, 76, 87.6, and 78 r per minute in output. The Lindemann window "ages" and does not transmit as well as when new. With a Küstner instrument, he found that 1,380 r produced an average erythema seventy-two hours after exposure. In eczema, he recommends from 250 r to 300 r, which may be repeated after eight days; in chronic types, as much as 550 r to 1,000 r; the interval must be from two to three weeks. In psoriasis, it is difficult to recommend definite doses; they fluctuate between 500 r and 1,000 r, according to the degree of hyperkeratosis. Before the X-ray exposure, ultra-violet radiation is usually applied. In lupus vulgaris, 1,400 r are given, repeated after four days until a total dose of 5,600 r has been reached. This treatment is combined with ultra-violet exposure and irradiation by ordinary roentgen rays in small doses, filtered through 4 mm. of aluminum. In acne vulgaris and rosacea, borderline rays are not recommended. In eczema of the eyelids, the author prefers borderline rays because he has never observed epilation in his cases. In patients whose skin is saturated for filtered roentgen rays, borderline rays can sometimes be used to advantage without fearing serious injuries to the skin.

E. A. POHLE, M.D., PH.D.

HEART AND VASCULAR SYSTEM (DIAGNOSIS)

Regarding a New Principle for the Determination of the Size of the Heart, and its Practical Applications. Chichio Tamiya. Fortschr. a. d. Geb. d. Röntgenstr., January, 1930, XLI, 62.

The author has constructed a new so-called bi-cathode tube which creates two beams of roentgen rays of diametrically opposite direc-

tions. One of these beams is used for fluoroscopy and orthodiagraphic focussing, according to Dr. Groedel. The second beam, conducted through a system of diaphragms, writes the contours which are seen and focussed fluoroscopically onto a film whenever a shielding window is opened. Both foci of this bi-cathode tube may be energized by one machine with four-tube-valve rectification, alternating phases of the current being conducted to the two anodes by suitable wiring, so that they receive alternating impulses. The bi-cathode tube is suitable for any other kind of roentgenologic work. It seems that this construction is quite original and convenient.

H. A. JARRE, M.D.

The Roentgen Findings in a Case of Primary Heart Sarcoma. Hans Fetzer. Röntgenpraxis, January, 1930, II, 23.

A case of primary heart sarcoma is described, with roentgen findings and autopsy report. The only abnormality in the heart shadow was a very definite bulge in the region of the pulmonary arch. There were definite areas of metastases in the lungs. The heart was not considered to be the seat of the primary sarcoma, either roentgenologically or clinically: only the autopsy cleared up the rather indefinite X-ray findings in the heart. It is extremely difficult to make a differential diagnosis from heart or pericardial diverticulum. Only the metastatic areas in the lung can lead one to suspect a primary malignant tumor of the heart, if combined with an unusual configuration of the heart shadow.

H. W. HEFKE, M.D.

LIGHT THERAPY

Our Experience with the Carbon Arc Light in Diseases of the Throat, Nose, and Ear. G. Osterwald. Strahlentherapie, 1930, XXXV, 523.

The author has used a carbon arc lamp in the Eye, Ear, Nose, and Throat Clinic in the University of Berlin, particularly in the treatment of tuberculosis of the upper air passages.

He presents the statistics of 72 males suffering from tuberculosis of the larynx. Sixty-four could be used in the statistics, 35 were favorable cases in the beginning, and 29 were advanced cases. Of the 35 patients, two died, two grew worse, three showed no improvement, and 28 were definitely improved. Of the 29 unfavorable, nine died, five grew worse, seven were not improved, while eight were improved. That means that in early cases, 80 per cent responded well to the treatment, while only 27 per cent of the advanced cases could be influenced. Of 35 women suffering from the same disease, 29 could be followed up, 16 were early cases, and 13 were advanced cases. Of the early cases, one died from carcinoma of the stomach, one grew worse, and 14 were improved. Of the 13 advanced cases, two died, two grew worse, five remained unchanged, and four showed improvement. This corresponds to 87 per cent improvement in early cases and 30 per cent improvement in advanced cases. The results of the treatment of lupus were also encouraging.

E. A. POHLE, M.D., PH.D.

The Effect of Light Rays on the Alexin in the Blood Serum. I.—The Effect of Ultra-violet Rays. O. Huntemüller. Strahlentherapie, 1930, XXXV, 489.

In normal adults who were exposed to the spectrum of a Jesionek lamp (quartz mercury vapor lamp), the alexins were found to be increased, sometimes as high as three times that of the pre-treatment level. This effect was much less in dark persons and also in frequently exposed persons whose skin had become pigmented. Further studies are under way as to the effect of other regions of the light spectrum.

E. A. POHLE, M.D., PH.D.

Jesionek's "Lightbiology": A Pioneer Work Published in 1910. C. Dorno. Strahlentherapie, 1930, XXXV, 22.

The author discusses each chapter of Jesionek's book on Lightbiology, followed by a review of the literature up to date showing the

development of this interesting branch of medicine. It shows how stimulating the publication of Jesionek has been toward further investigations. The extensive bibliography offers numerous references concerning the subject.

E. A. POHLE, M.D., PH.D.

Contribution to the Measuring Methods in Light Therapy. F. Bödecker. Strahlentherapie, 1930, XXXV, 549.

In 1912, Meyer and Bering published a chemical method for the calibration of the quartz mercury vapor lamp. It is based on the titration of iodin freed by the ultra-violet rays in a $KJ-H_2SO_4$ solution. A comparison of this test with the photo-electric cell method shows fair agreement between the two methods.

E. A. POHLE, M.D., PH.D.

Tissue Metabolism and Radiant Energy. Werner Kollath. Strahlentherapie, 1930, XXXV. 444.

The author studied the antagonistic effect of light of short and long wave length on the oxidation-reduction-potential in vital stained surviving cells. The details of the experimental method must be looked up in the original.

In beriberi pigeons, the muscles were stained blue following intraperitoneal injection of an alkaline methylene blue solution. Normal pigeons and fasting pigeons did not present this phenomenon. It appears that the reducing power of the tissue is decreased in beriberi pigeons, but increased in fasting pigeons. The oxidation power shows the inverse behavior. Microscopic examinations of the air sacs in the peritoneal cavity of pigeons injected with methylene blue revealed a difference in the histologic structure of the epithelium, depending upon the time interval between death of the animals and injection. Under the influence of a carbon arc light, the stained air sacs were discolored very quickly (reduction of the methylene blue to methylene white). The effective radiation belonged to the ranges of 5,330 Å. – 6,500 Å., and 7,600 Å. – 12,500 Å.

Since the discoloration took place also without exposure to light but after several hours instead of within a few seconds, it is concluded that the light accelerates a normal process. Cells which had been discolored by this light exposure showed a slight oxidation if they were exposed to light rays of short wave length. Red blood corpuscles with an unstained nucleus oxidized methylene white following exposure to the same light which reduced methylene blue. Carbon arc light without heat rays had the same effect. It is assumed that the point of attack of the rays is in the ferment discovered by Warburg, as far as the oxidation is concerned. For the reducing effect, there must exist another substance with opposite electrical charge. The stained oxidized phase, which has very few electrons, corresponds to the positive pole, and the discolored and reduced phase, rich in electrons, corresponds to the negative pole of the potential.

The relations of these observations to certain diseases are then discussed.

E. A. POHLE, M.D., PH.D.

LIPIODOL INJECTIONS

The Present Status of Hysterosalpingography: With a Review of the Literature and a Report of 512 Personal Cases. E. R. Witwer, H. P. Cushman, and T. Leucutia. Am. Jour. Roentgenol. and Rad. Ther., February, 1930, XXIII, 125.

The authors have made an extensive review of the literature on hysterosalpingography and present their diagnostic findings in a profusely illustrated article. In 512 cases examined by lipiodol injections, the only accident observed was a single case of ruptured tube, which was found at operation the following day, although, meanwhile, the patient had suffered no symptoms as a result of the rupture. Contra-indications to the procedure are: Recent hemorrhage, inflammatory conditions not completely quiescent, active infection or malignancies of the cervix, previous intra-uterine interventions, ectopic gestations, or uterine gestation where therapeutic abortion is not indicated, infected

cervical or uterine polyps, and fever. The preferred time for injection is from 8 to 10 days following menstruation. The "closed cervix" method is utilized but it has not been found necessary or entirely satisfactory to use a manometer; however, care must be exercised not to increase the pressure beyond the accepted safe limits of from 200 to 240 mm. mercury. The method has been proven to have great diagnostic value in anomalies of the genital tract, in tubal affections producing sterility, in selected cases of early pregnancy where therapeutic abortion is indicated, or where a differential diagnosis is essential, in non-malignant uterine tumors, and in extra-uterine pelvic tumors.

J. E. HABBE, M.D.

MEASUREMENT OF RADIATION

Comparative Measurements with the Küstner Instrument, the Martius Ionometer, and the Sabouraud-Noiré Tablet, for Dosimetry in Superficial Therapy. Martin Schubert. Strahlentherapie, 1930, XXXV, 553.

The Sabourand-Noiré Tablet was compared with two ionization instruments in a beam of roentgen rays produced at 110 K.V., no filter, 0.5 to 1.0 and 2.0 mm. aluminum. The corresponding values for erythemas of the same degree were found to be at 650 r-, 624 r-, 684 r- and 667 r-units. There was evidently no dependence of the wave length on the erythema reaction within the range examined. The author feels that the Sabouraud-Noiré method can be used in superficial therapy in connection with a sphere gap. However, for accurate dosage, an ionization instrument with a chamber as independent of the wave length as possible, is preferable.

E. A. POHLE, M.D., PH.D.

Stereoroentgenometry: A Method for Mensuration by Means of the Roentgen Ray. Clayton R. Johnson. Am. Jour. Surg., January, 1930, VIII, 151.

This paper concerns a process for determining the solid dimensions of a radiopaque ob-ject from its stereoscopic roentgenograms, applicable to all those conditions wherein the knowledge of solid dimensions may be of value in diagnosis. This method is somewhat similar to that described by Sir James Mackenzie Davidson, in 1898, for localization of foreign bodies. It is quite accurate for pelvimetry as well. The author goes into great detail in describing all the steps in this method. It is impossible, however, to abstract his paper in an intelligible way without reproducing the illustrations referred to in the text. It is well worth detailed study by anyone interested in pelvimetry or the localization of foreign bodies.

HOWARD P. DOUB, M.D.

PAGET'S DISEASE

Osteoporosis Circumscripta Schüller—A Rare but Typical Manifestation of Paget's Disease. Konrad Weiss. Fortschr. a. d. Geb. d. Röntgenstr., January, 1930, XLI, 8.

Schüller, in 1929, published a series of cases showing, as characteristic changes, extensive, sharply demarcated areas of resorption, involving large portions of the cranial vault. While the author is uncertain about the etiology of these changes, he feels inclined to consider them as manifestations of Paget's disease in other portions of the skeleton, thus confirming Schüller's opinion about the etiology of these cranial affections. One case with rather extensive cranial pathology, also reveals, as a single clinical sign, marked tympany on percussion over the affected portion of the cranial vault, which previously was described as a symptom of Paget's disease by Gross, Mayer, and Vogl. Discussing the etiology and development of osteoporosis circumscripta and other manifestations of Paget's disease, the opinion is stressed that osteoporosis apparently is a developmental stage of Paget's disease, as Eisler, in 1922, reported an instance where the typical appearance of Paget's disease succeeded the typical picture of osteoporosis circumscripta though in a long bone. Paget's manifestations in the pelvis also, according to Kienböck, not infrequently are found as extensive areas of re-

sorption of lime salts, entirely resembling this type of osteoporosis. Observations on these two cases lead to the conclusion that osteoporosis circumscripta and Paget's disease are not merely related diseases, but that osteoporosis circumscripta is a rarely occurring typical manifestation of osteitis deformans.

H. A. JARRE, M.D.

RADIUM

The Use of Radium in the Treatment of Rectal Carcinoma. J. P. Lockhart-Mummery. Brit. Med. Jour., Jan. 25, 1930, No. 3603, p. 139.

Radium may be used in three ways in the treatment of rectal carcinoma: (1) As an adjunct to excision, thereby enabling a less serious operation to be performed; (2) in the treatment of cases that are surgically inoperable; (3) as a substitute for the operation of excision. At the present day it is generally agreed by surgeons that the only justifiable treatment for even an early case of carcinoma of the rectum is complete removal of the rectum and surrounding tissues, with the establishment of a permanent colostomy opening. With this method the proportion of cures (based on a five years' survival) is now over 50 per cent. This operation, however, is a mutilating one, and the technic herein described, whereby, with the suitable use of radium, the patient is saved a permanent colostomy, will, if the proportion of cures still remains high, be a great advance over present methods.

(a) As an adjunct to excision:—The cases treated so far have been very early growths in the middle or lower part of the rectum on the posterior wall. The author's technic is as follows: (1) Removing coccyx and necessary portion of sacrum and freeing rectum; (2) local removal of the growth, together with a half-inch margin of healthy tissue; (3) closure of rectal wound by transverse sutures and sewing of muscles back into place; (4) placing of radium needles in the mesorectum, along the line of lymphatic spread on each

side of the rectum, and in the tissues in the immediate neighborhood; (5) closure of the back wound except for a small drain, the threads attached to the radium needles being left inside the wound; (6) drainage of the rectum by a large tube through the rectum; (7) at the end of a week, the re-opening of the wound and the removal of the needles, in such a way that free drainage is provided. Cases thus treated have done well to date, function being perfectly restored and the bowels acting in a normal manner. If the results in these cases are good as regards recurrence, which time alone will show, then we have a method in suitable cases which will enable a colostomy to be dispensed with, and a normally functioning rectum to be left.

(b) As a substitute for excision:—The results of radium treatment at the present time do not justify it being used in place of excision in operable cases, but the best results that the writer has seen have been in cases of epithelioma of the anus in elderly persons.

(c) In inoperable cases:—The technic is still in the experimental stage. Most of the cases treated have been in this category. The tendency has been towards smaller doses spread over a longer period of time, with the aim of decreasing the severity of the local reaction. It has also been found an advantage to increase the total dosage up to 6,000 mg.-hrs., and at the same time increase the screening. The author's method of exposure is similar to that outlined under "(a)," the needles being placed roughly parallel to the lumen of the bowel to avoid perforation and unnecessary infection. If the growth is on the anterior wall of the rectum it is barraged from the front by exposing the rectum by an incision across the perineum. In all cases the abdomen has to be opened and needles, or preferably radon seeds, inserted into the upper part of the mesocolon and the areas on each side of it. All the early cases developed a plastic peritonitis due to the radium, which has to be drained.

The chief difficulties are gaining access to the growth, and sepsis.

W. D. MACKENZIE, M.D.

Radium Teletherapy: Note on the Apparatus at Present in Use at the Westminster Hospital with Four Grams of Radium. Francis Rock Carling. Brit. Med. Jour., Feb. 8, 1930, No. 3605, p. 232.

This apparatus was designed to meet the problem of making the most effective though economical use of the radium, and at the same time to afford proper protection of all persons, except those actually under treatment, from the emanations. The radium is used in a "bomb," being placed inside a lead shield in five containers. The apparatus is constructed so that two patients may be treated simultaneously, one above and one below the lead shield containing the radium, while in the horizontal plane, the average protection provided amounts to some six inches of lead. When not in use the radium containers are withdrawn radially from the cylindrical hollow center until they are buried in the lead mass. The separation into containers reduces the skin intensity and flattens the isodose lines, while only slightly reducing the dose at a depth. The dimensions of the "radiant beam" can be controlled by a system of cylindrical lead plugs. The screenage, amounting to the equivalent of just over 1 mm. of platinum, consists of monel metal, brass, aluminum, and wood.

W. D. MACKENZIE, M.D.

SKIN (GENERAL)

Investigations Concerning the Heat Distribution in the Skin Following Intense Exposure to Visible Light. Svend Lomholt. Strahlentherapie, 1930, XXXV, 324.

The author reports the results of his investigations of the heat distribution in the skin following exposure to carbon arc light, filtered in such a manner that only radiation between 5,700 Å. and 9,000 Å. were transmitted. The reflection, which was determined by direct calorimetry, amounted to about 30 per cent. About 9.5 per cent is due to simple reflection while the balance is due to dispersion. The absorption of dead skin and of living skin is of the ratio of 1.4:1; in other words, dead skin absorbs more than living skin. The skin

of man, rabbits, and rats showed nearly identical behavior. The heat distribution in the skin following exposures up to toleration was determined by means of small colorless toluol thermometers which were embedded in skin folds. Behind the skin layers of 1.1, 1.4, and 5.0 mm. thickness, the temperatures were 41.0, 40.0, and 37.7 degrees Centigrade, respectively. The heat conductivity of dead skin was found to be much less than that of water. The absorption of blood in a layer of 0.3 mm. thickness amounted to about 55 per cent. The analysis of a piece of irradiated skin showed that the blood content amounted to only 1.2 per cent of the total weight of the specimen. The author concludes from this that the major part of the light is not absorbed by the blood, but by other components of the skin. From his observations, it seems improbable that even the most intensive exposure to carbon arc light will increase the body temperature above that of the highest fever.

E. A. POHLE, M.D., PH.D.

On the Dependence of Pigment Formation on the Wave Length of the Radiation. Erich Uhlmann. Strahlentherapie, 1930, XXXV, 361.

The author exposed human skin to monochromatic radiation, obtained by means of a quartz spectrograph. He could confirm the work of Hausser and Vahle, and verified the erythema maxima at 2,970 Å., 3,030 Å., also at 2,480 Å., and 2,540 Å. The relation between pigmentation and wave length was not so simple. There was a maximum at 2,480 Å. and 2,540 Å., also at 3,130 Å. and 3,160 Å. The latter two, however, were not so pronounced and could be observed only in certain cases. This observation also explains the well known difference in the pigmentation produced by the quartz mercury vapor lamp and by the sun.

E. A. POHLE, M.D., PH.D.

SKIN (THERAPY)

Roentgen Sterilization in Impetigo Herpetiformis. O. Grütz. Strahlentherapie, 1930, XXXV, 501.

The author relates the history of a woman

thirty-five years of age who developed a skin disease about one year after her first pregnancy. The symptoms recurred and the disease was diagnosed as impetigo herpetiformis. Symptomatic treatment improved the condition, but, following the first menstruation after childbirth, a new and very severe recurrence appeared. Since the condition was always worse at the time of menstruation, a temporary sterilization was carried out. This was followed by amenorrhea for a period of about six months, during which time the skin eruptions did not reappear. The first menstruation occurred after seven months and there was a prompt reappearance of the impetigo. The calcium in the blood was found to be d creased to about 50 per cent of the normal value, while the basal metabolic rate was increased to 131 per cent. The woman has decided to undergo permanent sterilization if the disease recurs again. The author then discusses the possible theory for explaining this observation.

E. A. POHLE, M.D., PH.D.

Our Experience Concerning Dosage and Filtration in Roentgen Therapy of Skin Diseases. E. Galewsky and Karl Linser. Strahlentherapie, 1930, XXXV, 561.

The authors recommend the use of small doses of lightly filtered roentgen rays in the treatment of skin diseases. In psoriasis, eczema of the lids and lips, and in pruritus ani, this is particularly essential. Not only are late reactions very improbable but the results are, in the writers' experience, much better.

E. A. POHLE, M.D., PH.D.

Treatment of Skin Tuberculosis with Trypaflavin (Neutral Acriflavine) and the Quartz Mercury Vapor Lamp. W. Frieboes. Strahlentherapie, 1930, XXXV, 528.

The author describes the treatment of tuberculosis of the skin as practised in his clinic. He first applies 5 per cent pyrogallol ointment and then exposes the lesions to the quartz mercury vapor lamp. Shortly before the ex-

posure, 5 c.c. to 10 c.c. of a 1 per cent trypaflavin solution is given intravenously. Up to thirty and forty injections were given in a single case without any serious consequences. He believes that the cosmetic results are much better with this combined treatment. A diet low in sodium chloride is also recommended.

E. A. POHLE, M.D., PH.D.

X-ray Treatment of the Commoner Microbic Diseases of the Skin. J. B. Higgins. Brit. Med. Jour., Dec. 21, 1929, No. 5598, p. 1152.

There are many explanations as to the biological changes produced in the individual skin cells exposed to X-ray. Among these the foremost are the theories of Hertwig, Packard, Holzknecht and Caspari. The fact remains, however, that small doses of X-ray have a decidedly stimulating effect on certain skin diseases, and at the present day X-ray ranks as one of the most reliable factors in their treatment. The greater sensitivity of diseased cells, which is always present, permits the administration of an effective dose, but, in the presence of hyperemia accompanying the pathological condition, we have the added factor of a skin which has become definitely hypersensitive, thus cutting down the margin of safety between stimulation of the affected cells and injury to the surrounding hyperemic skin. The apparatus used at the Manchester Skin Hospital consists of a 16-inch coil. The rays are emitted from a Coolidge tube and are of a quality produced by a kilovoltage of 120 and a milliamperage of $3\frac{1}{2}$, *i.e.*, soft and medium rays at an equivalent spark gap of $6\frac{1}{2}$ inches. Under these conditions an erythema dose (Sabouraud pastille) can be produced in approximately two minutes at an anticathode distance of 8 inches.

Acne vulgaris (including acne indurata): Dosage consists of a preliminary course of three or four half skin doses, unfiltered, and administered with intervals of seven days between doses. Following this a similar course is given, but a filter of 0.5 mm. of aluminum is used. An average of five to six skin doses in

each case is required to produce a cure. It would appear that the curative effects of X-rays on acne depend not so much on the degree of filtration, or quality of the rays employed, as on the total quantity of the latter which are absorbed by the skin. The actual amount of absorption required to produce a cure depends on: (*a*) the type of skin to be treated; (*b*) the interval between the treatments. The shorter the interval between treatments, the greater the cumulative effects of the rays. Most cases can be cured in approximately seven or eight weeks, with no ill effects. Any inhibitory effect on the growth of the bacillus which might occur may be regarded as negligible.

Sycosis vulgaris or sycosis pyogenica: Here hyperemia is almost invariably associated, so one is dealing with a hypersensitive skin. Certain general principles must be observed if one is to avoid disaster. First, an acutely inflamed skin should on no account be treated by X-ray until some successful effort has been made by other means to reduce the hyperemia.

Three methods of treatment are open to the radiologist: (1) Epilation of the beard; (2) stimulation of the affected cells; (3) a combination of these methods. In very hyperemic cases it is best to administer small stimulating doses (one-third skin dose at weekly intervals). The greatest success from the radiological standpoint is obtained in those cases which show practically no hyperemia. The dosage may be carried to the point of epilation, which appears to be the ideal method of treatment. It has been the author's experience that, while the mild stimulation of the infected beard produces marked improvement in most cases, a complete cure cannot be hoped for through the medium of X-rays alone as long as infected hairs remain. Sycosis is treated, except in a few cases, without the use of filters. It would be reasonable to assume that the use of a thin filter would allow the administration of rather larger dosage, but too heavy filtering is liable to result in unpleasant consequences, such as temporary paralysis and swelling of the salivary glands. The method of treatment by super-soft rays (G. Bucky and J. J. Eller) which gives good results in sycosis, paronychia, and carbuncles, is as yet in its infancy.

W. D. MACKENZIE, M.D.

Dermatoscopic Findings in Normal Skin Following Application of the Water-cooled Quartz Mercury Vapor Lamp under Compression. Max Popper. Strahlentherapie, 1930, XXXV, 539.

The author studied changes in the skin following exposure to the water-cooled type of quartz mercury vapor lamp and to the Finsen lamp, with the dermatoscope. He found that the reactions to the lights were very similar in many respects. However, the quartz mercury vapor lamp had a more superficial effect, with injuries to the epidermis, while, following the Finsen treatment, a direct effect of the radiation on the epidermis and on the cutis could be observed. The reactions in the cutis appeared to be increased following the exposure to the Finsen light; in cases of irradiation with a quartz mercury vapor lamp, they appeared to a much lesser degree and only after the inflammatory reaction had subsided.

E. A. POHLE, M.D., PH.D.

THE SKULL

Encephalographic Visualization of the Cisternæ at the Base of the Skull and Their Diagnostic Evaluation. K. Goette. Fortschr. a. d. Geb. d. Röntgenstr., January, 1930, XLI, 1.

Exact knowledge of the subarachnoid spaces at the base of the brain is of considerable diagnostic importance, because pathologic changes can be utilized for the localization of cerebral changes, especially in the posterior fossa. To study these spaces, human brains were injected or painted with contrast media, and, subsequently, roentgenograms made which were compared with encephalograms. The longitudinal fissures to both sides of the falx, the sulcus corporis callosi and cinguli, the cisternæ ambiens, interpeduncularis and the Sylvian fissure, are fairly well known. Particular attention in these studies

was paid to the so-called choreoid fissure, which is a space located between the posterior pole of the thalamus, especially the pulvinar, and the adjacent portion of the posterior and temporal lobes next to the fornix. This space continues upward into the velum triangulare; while it is usually short and well closed off by fusion of both leaves of the pia-arachnoid, occasionally it may be found extending far underneath the corpus callosum. Photographs of several injected specimens and encephalo-grams, some of them purposely obtained with slight cranial tilting, illustrate the exact loca-tion of this fissure and its relation to the other basilar cisternæ. Two cases are recorded in which the exact study of these fissures led to correct diagnoses, one in which a walnut-sized glioma in the left temporal lobe, poste-rior portion, was localized; a second one in which hemorrhage into the internal capsule was diagnosed.

H. A. JARRE, M.D.

Stereo-projection of the Skull. Werner Teschendorf. Fortschr. a. d. Geb. d. Rönt-genstr., January, 1930, XLI, 17.

Optimal roentgen stereoscopy requires spe-cial projections different from the standard projections commonly in use. Oblique pro-jections are especially advantageous because the stereoscopic image will appear the more plastic, the more lines are combined to the visual impression of planes. When the axis of the radiating beam and its incidence upon the object is marked, any projection of the cranial structures may be characterized. The author is using a cap which contains three tapes equipped with opaque markers, placed at one centimeter distance. One of these tapes surrounds the base of the skull; a sec-ond one is placed along the sagittal suture, and a third one across the calvarium from one auricular meatus to the other. A chart added to this paper shows a number of oblique or semi-oblique positions, employed for advan-tageous stereoscopic visualization of such structures as the optical canal, the sella turcica, the mastoid process and auricular meatus, the petrous portion of the temporal bone (this

latter in three different projections), the base of the skull, including the foramen magnum, the occipital condyles and the foramina trans-versalia, the maxillary antrum, and the frontal and sphenoid sinuses. A number of stereo-scopic roentgenograms which may be viewed with a small hand-stereoscope, illustrate the advantages of this method.

H. A. JARRE, M.D.

Roentgen Rays and So-called Hemato-encephalic Barrier. B. Mogilnitzki and L. Podljaschuk. Fortschr. a. d. Geb. d. Rönt-genstr., January, 1930, XLI, 66.

The finest method of microscopical technic revealed no alteration in the nervous elements of the cerebro-spinal system upon roentgen ir-radiation. It was anticipated, however, that molecular pathologic changes might occur with a disturbance in the equilibrium of colloids. Changes due to irradiation could be found in the mesenchymal elements of the central ner-vous system (proliferation of vascular endo-thelium), but such changes were not constant and varied widely in degree with different in-dividuals. Using the methods of vital staining with trypan blue and iron, it was found that a single irradiation of the skull of rabbits and young dogs would change the usual reaction of the mesenchymal elements, and that the re-peated irradiation with moderate doses could produce physico-chemical changes besides morphologic pathology. These changes are irregularly distributed throughout the cere-brum. It was concluded that the so-called hemato-encephalic barrier is morphologically represented by the cerebral blood vessels, capil-laries, and also by the mesoglia.

H. A. JARRE, M.D.

THE SPINE (DIAGNOSIS)

The Calcification of Intervertebral Disks and its Clinical Significance. Th. Rövekamp. Röntgenpraxis, Feb. 15, 1930, II, 186.

The author describes the clinical and roent-genological findings of calcified intervertebral disks. Definite pain over the affected area, ra-

diating towards the legs, decreased motility, the history being one of long standing, make this symptom-complex a rather definite one. The etiology is uncertain and therapeutic means are usually of no avail.

H. W. HEFKE. M.D.

A Clincal Report of Nineteen Cases of Fractured Transverse Processes Producing Symptoms Simulating those Referable to the Kidneys. I. S. Trostler. Ill. Med. Jour., March, 1930, LVII, 192.

In the words of the author: "Fractures of the transverse processes of the lumbar vertebræ are not rare, but a series of nineteen cases which gave symptoms referable to the kidneys, none of which showed shadows which might be diagnosed as kidney stones, seems to me to be of sufficient interest to present at this time."

Of these cases thirteen were in men and six in women, and all but three gave a definite history of severe trauma in the lumbar region, from three to twenty-five years previously. The exceptions were recent injuries. Five of the cases were operated upon, the injured process and its periosteum removed, with complete relief of symptoms referable to the kidneys.

C. H. DeWitt, M.D.

Head Sling Traction Technic in Cervical Spine Roentgenography. Philip Lewin. Am. Jour. Surg., February, 1930, VIII, 434.

The author shows a method of examining the cervical spine in certain cases, such as torticollis. The examination is made in such a manner that considerable extension is accomplished by traction on the head. This produces some separation of the cervical vertebræ, with an increased delineation of these bones.

Howard P. Doub, M.D.

Correction of Compressed Fractures of the Vertebræ. John Dunlop and Carl H. Parker. Jour. Am. Med. Assn., Jan. 11, 1930, XCIV, 89.

Compression fractures of the vertebræ are discussed. The frequency of compression

fractures in accidents to workmen makes this injury of great importance to industrial surgeons. Roentgenograms are made to check the measurements of the contour of the bodies before and after reduction. In the authors' series the best reductions were accomplished when the injury was below the ninth dorsal vertebra.

The report and the discussion present a very interesting review of this subject.

C. G. Sutherland, M.B. (Tor.)

Dislocations of the Cervical Vertebræ: Report of Thirty Cases. Mitchell Langworthy. Jour. Am. Med. Assn., Jan. 11, 1930, XCIV, 86.

Dislocations of the cervical vertebræ are reviewed by Langworthy. Seventeen cases of bilateral and thirteen of unilateral dislocation are reported. These were treated with excellent results by the reduction manipulation of Walton.

C. G. Sutherland, M.B. (Tor.)

THE THYROID (THERAPY)

Concerning the Relationship between Fibroids of the Uterus and the Thyroid Gland. Frederick Howard Falls. Calif. and Western Med., November, 1929, XXXI, 305.

In a thousand women with fibroids of the uterus, there was no evidence that goiter was caused by the fibroids. Fibroids complicated by adnexal pathology and degenerative changes were not associated with a higher incidence of thyroid disease than other cases. The basal metabolic rate in a series of thirty-five cases, while higher than normal in the majority of cases, was not sufficiently so to be of special significance. In a series of one hundred thyrotoxic patients, there was no evidence of an abnormal incidence of fibroids as judged by the symptoms, vaginal findings, and history of operation for fibroids. Only 2 per cent of these cases had demonstrable fibroids. Fibroids and hyperthyroidism may occur in the same individual. The treatment of the thyroid should always precede that of

the fibroid unless the latter is an emergency, as twisted, infected, necrotic, or severely bleeding fibroid, and if emergency operation is necessary, adrenalin as a stimulant for shock should be avoided.   Rest, Lugol's solution, and lobectomy may be necessary before attempting the necessary gynecological operation. Palliative management of the fibroid by radium, X-ray, ergot, and pituitrin, with blood transfusion in suitable cases, often give good results while the thyrotoxicosis is being brought under control.   All patients with fibroids giving suggestive history or symptoms of thyroid disease should have a careful examination, including basal metabolic rate, to determine the presence and degree of thyrotoxicosis.

FRANCIS B. SHELDON, M.D.

TUMORS (DIAGNOSIS)

The Roentgen Diagnosis of Lipomas and its Practical Significance.   Adib Chasin. Röntgenpraxis, March 15, 1930, II, 282.

Fat tissue absorbs roentgen rays to a lesser degree than any other soft tissue of the body, which makes it possible to demonstrate lipomas, especially in the extremities.   Differentiation from other soft tissue tumors is fairly easy, and only a projection of the lipoma into the bone shadow may make it impossible to demonstrate it.   A tumor shadow having about the same density as the surrounding muscle must be considered as of non-fatty nature.

H. W. HEFKE, M.D.

Differential Points in the Diagnosis of Lung Tumors.   Robert Gantenberg. Röntgenpraxis, March 15, 1930, II, 241.

A series of interesting intrathoracic tumors is reported by the author, consisting of primary and secondary carcinomas of lung and pleura, and mediastinal tumors.   One must not expect to make a definite diagnosis from a roentgen examination alone in many of these cases.   Repeated examinations and observations of the clinical course of the disease were sometimes necessary to achieve it.   In order to avoid mistakes one should always remember that tuberculosis in the form of the "early infiltration" may sometimes present itself as a round, well circumscribed shadow, especially in the subclavicular region.   The clinical findings are of great importance in tumors of the mediastinum, particularly in Hodgkin's disease, which may show many different pictures.   Fluoroscopy in the oblique and lateral positions should not be omitted; the situation of the tumor may be of great importance for the differential diagnosis.

H. W. HEFKE, M.D.

An Outline of the Diagnosis of Spinal Cord Tumors.   Kenneth G. McKenzie. Can. Med. Assn. Jour., December, 1929, XXI, 696.

The author enumerates the various steps to be taken in the diagnosis of spinal cord tumors, *viz.*, examination for changes in sensation; examination for muscle weakness, atrophy of muscles and changes in the reflexes; examination for disturbances in the function of the bladder or rectum, and examination of the spinal fluid.   The last named makes for earlier and more exact diagnosis.   Details of the examination are the test for globulin, the cell count, and the Wassermann reaction test.

As a tumor of the cord tends to block the cerebrospinal fluid pathway about the cord, a number of tests, all associated with spinal puncture, have been devised to locate the site of blockade.   The Queckenstedt test makes use of difference of pressure of the cerebrospinal fluid, as indicated by the manometer, when the jugular veins are manually compressed.   If there is a block in the cerebrospinal fluid pathway, the pressure will not change; if there is no block, the pressure will rise as the jugulars are compressed.   If, however, the block is only partial, this test is very difficult to interpret.   The Ayer test is then employed.   This consists in a double puncture, one above the site of the lesion and one below. If there is even a partial block, the difference between the rise and fall of the cerebrospinal fluid in the two manometers is very striking.

If, by means of the Queckenstedt or the Ayer test, it has been established that a block

exists, but the site of the block has not been determined with sufficient accuracy, then—and only then—is lipiodol injection employed. One cubic centimeter is injected into the cisterna magna, and fluoroscopic and radiographic examinations made in the upright position. If there is complete obstruction, operation should be performed within forty-eight hours, before the lipiodol becomes encysted by an inflammatory reaction. After the tumor has been removed, the head of the patient's bed is kept raised for a week, to make sure that the lipiodol finds its way to the bottom of the lumbar sac, where it becomes encysted and apparently gives rise to no trouble.

L. J. CARTER, M. D.

TUMORS (THERAPY)

Clinic on Malignant Diseases. Presented by the Staff of the Memorial Hospital, New York City, Sept. 19, 1929. Am. Jour. Surg., January, 1930, VIII, 122.

(This is the report of a clinic, showing the types of disease treated and the methods used.)

Giant-cell Tumors of Bone: With Special Reference to Treatment Technic. R. E. Herendeen.—The author reports three cases of giant-cell tumors, all treated with X-ray therapy, and all showing a very satisfactory result. The third case demonstrated the development of tumors, similar to the primary one, at various parts of the body, but all these responded satisfactorily to radiation therapy.

Types and Treatment of Bone Sarcoma. William B. Coley.—This author discusses the osteogenic and endothelial myeloma of bone. The osteogenic type, associated with considerable new bone formation, has been found both extremely radioresistant and also rarely curable by amputation. Amputation followed by prophylactic treatment with mixed toxins of erysipelas and *Bacillus prodigiosus* has, in the writer's hands, given far better results. In forty cases of osteogenic sarcoma, including the endothelioma type, but excluding the giant-cell, the end-results showed 50 per cent of

the patients to be alive in from five to twenty-five years. He does not believe that radiation therapy, alone or followed later by amputation, is as satisfactory as early amputation alone. In the endothelioma type of bone sarcoma, radiation therapy and toxin therapy should be employed, and an attempt made to save the limb.

In Coley's opinion, the present method of choice in the treatment of giant-cell sarcoma of the long bones is a very extensive curettage, swabbing out of the cavity with zinc chloride or pure carbolic acid, followed by a two or three month period of toxin treatment. He admits, however, that most of these cases can be treated satisfactorily by radiation therapy, but states that one out of four cases are found to be malignant.

The Malignant Granulomas. Lloyd F. Craver.—In this paper the author presents Hodgkin's disease, lymphosarcoma, and thymoma. He believes that occasionally the tumors which are apt to show the most radioresistance, present clinical evidence of considerable venous stasis, and the supraclavicular lymph nodes are apt to be very hard, stridor being present. On the other hand, those cases of thymoma which have shown penetration of the chest wall have been found to be rather radiosensitive. In the treatment of these deep-seated intrathoracic tumors, a moderately high voltage X-ray therapy—from 175 to 185 K.V. —is administered.

Neoplasms of the Vulva. William P. Healy.—In the three cases which he reports, the neoplasm developed on a pre-existing skin lesion. All of the cases had leukoderma, with thickening of the skin locally. Practically all tumors in this area are histologically of the adult, fully developed squamous variety of cancer, and, therefore, are relatively radioresistant. As the inguinal glands are practically always involved, both groins should also be irradiated. Following this treatment Healy favors vulvectomy, with dissection of one or both groins. He also follows this with heavy radiation therapy.

Malignant Growths of the External Genitalia. Benjamin S. Barringer.—In carcinoma of the bladder, the treatment at the Memorial

Hospital for the past fifteen years has been by means of radium implantation into the growth. No matter how accessible the growth for operative removal, this latter has never been attempted. In the majority of cases implantation is made under direct vision through the open bladder. The operative mortality of radium implantation in a cystotomy wound has been between 3 and 4 per cent. With this treatment they have been able to cure cases which were beyond operation, and the percentage of control in both papillary and infiltrated carcinoma is better than that shown by operative statistics. In prostatic carcinoma, deep X-ray therapy is given through five portals of entry, and, in addition, where the growth is small and confined to the prostate, gold radium seeds are implanted through the perineum into the carcinoma. The problem of residual urine is dealt with by a minor operation, namely, punching out the obstructive portion of the prostate through the urethra.

Rectal Cancer: Principles and Methods of Treatment at the Memorial Hospital. George E. Binkley.—A routine method of treatment is not employed, due to the varying factors which must be taken into consideration, namely, the condition of the patient, the stage of the disease, the location of the tumor, the degree of malignancy of the cells, and the degree of radiosensitivity of the cancer cells. Radiation therapy forms the basis of treatment, but colostomy and radical surgical excision are supplemented in all cases in which surgical interference offers an additional advantage. The types of radiation therapy now employed consist of external applications of radium and high voltage roentgen rays and interstitial applications of gold filtered emanation seeds.

Cancer of the Breast Treated Exclusively by Radiation Therapy. Burton J. Lee.—The treatment of cancer of the breast is often more difficult than that of cancer in other regions of the body, because of the widespread lymphatic system here encountered. Because of the disappointing results from the radical operation, the attempt has been made to control cancer of the breast in certain cases by irradiation alone. Several cases are presented, showing results and method of treatment.

Two of the cases are recent, but show evidence of regression of the growth. The third patient, after eight and one-half years, shows no evidence of carcinoma remaining in the breast. The pathological report in 1920 was carcinoma simplex.

Fixed Pre-calculated Irradiation Dosage of Intra-oral Epidermoid Carcinoma. Douglas Quick and G. Failla.—The writers have made a detailed study of tissue doses received by tumor masses in successfully irradiated cases of intra-oral carcinoma. This has led them to believe that the lethal dose of the average intra-oral squamous carcinoma lies between seven and ten skin erythema doses, if delivered within a period of about ten to twenty days. From this experience in suitable cases, they have delivered to the tumor masses a pre-determined dose, and present three cases to show the results of this procedure.

Some Types of Radioresistant Tumors, with Results of Treatment. James Ewing.—The author presents several cases to emphasize the following points: (1) That the factors entering into radioresistance are varied; (2) that each tumor must be analyzed by itself in accordance with its known structure and clinical behavior; (3) that the results to be attained by radiotherapy in these tumors must be considered in the light of all the factors. Growth-restraint is generally all that should be attempted. He presents two cases of malignant bone tumors, the patients being alive about eight years after treatment by radiation therapy, followed several years later by amputation. One case of giant-cell tumor containing bone aneurysm was given radiation therapy and was later amputated, because of the aneurysm. In this case the radioresistance is apparent, not real. Two cases of neurogenic sarcoma were treated and were shown to be highly radioresistant. A case of liposarcoma of the capsule of the knee joint was also treated, but was found to be very radioresistant. In other cases, this type of sarcoma has responded to radiation. The last case was one of diffuse endothelioma of the upper end of the tibia. This was treated with radium packs, but three years later there was a recurrence of the growth and amputation was done. The sec-

tion revealed that the main tumor had been rendered highly fibrous and quiescent, but that the fibrous tissue contained many groups of well-stained viable tumor cells. The conditions represent abortive fibrosis.

HOWARD P. DOUB, M.D.

Pseudomucinous Cystadenoma: Analysis of Thirty Cases in which the Cysts were not Ruptured before Operation. James C. Masson and Robert Hamrick. Surg., Gynec. and Obst., April, 1930, L, 752.

Histological classification and a review of the frequency of these lesions, as reported by various authors, are given. An analysis of 30 unselected cases of surgical removal, unruptured before operation, is presented. The average age is 48.4 years, with range from 24 to 71 years, the greatest number (11) being in the sixth decade of life. Eight cases were malignant as determined by microscopic examination, with the average age of these cases being 55 years.

Symptoms given are: Gradual onset and progressive enlargement of abdomen, increase of intra-abdominal pressure, sensation of bearing down, urinary frequency, and dysuria. The average duration of symptoms was 20.2 months. In seven of the cases reported as malignant, the average duration of symptoms was 7.7 months. Cysts varied in size from 6 mm. to a mass larger than a normal pregnant uterus with an average from 15 to 30 cm. in diameter. The right and left sides were involved about equally in frequency when unilateral involvement was noted. Invasion was bilateral in 22.2 per cent of the benign cases, and 28 per cent of the malignant cases. No post-operative deaths.

One case (benign) had pre-operative roentgen-ray treatment before coming to the clinic. Five of the patients with malignant pseudomucinous cystadenomata had roentgen-ray and radium treatment post-operatively. A report of 18 of the 22 cases with a benign lesion is given, and of the eight which had malignant lesions. Of the latter group, two are dead; one 2 years 4 months after operation, and the other 3 years 7 months after operation. The

last case had no post-operative radiation treatment and died apparently from recurrence. Five of the others have no reason to believe the pathological condition has recurred. The authors state that the treatment is surgical and "the use of roentgen ray and radium after operation is advisable in those cases in which evidence of a malignant condition is found by microscopic examination." There is no mention of the quality or quantity of the radiation which was used.

D. S. CHILDS, M.D.

URINARY TRACT

Roentgenography of the Kidneys and Urinary Tract by Means of Intravenous Injection of a New Contrast Medium—Uroselectan. M. Swick. Klin. Wchnschr., Nov. 5, 1929, VIII, 2087.

While investigating the excretion of selectan-neutral, which had been used therapeutically in the treatment of different coccus infections, it was discovered that excretion was more marked through the kidneys than through the bile. The first results by intravenous injection of animals were only sufficiently satisfactory to indicate the possibility of the method—whether or not the affinity for the kidney and the solubility of the substance could be improved. Oral administration in man was not successful. Continued investigation with the co-operation of the Chemical Institute finally evolved a substance which answered the requirements of safety, free solubility, and marked excretion by the kidneys. This has been named uroselectan. The iodine content of this drug is 42 per cent. It is well tolerated intravenously by mice and squirrels, and when injected intravenously in man, in proportionately much smaller amounts, yields very satisfactory pyelograms. The density of the roentgenogram depends directly on the condition of the kidney, as does also the time at which the best roentgenogram is obtained. The latter varies from one to two hours in the presence of good kidney function; to twenty-four or even thirty-two hours in poor function. When function is very

poor, no shadow is obtained. Whether normally or slowly excreted, the drug is not demonstrable in the blood after fifteen minutes. What becomes of the substance when not excreted has not been determined. In the clinical tests there were no deleterious effects of consequence. Death nineteen hours after injection in a girl of ten years of age was shown to be due to the severe and advanced nature of the pathologic conditions. The conclusion is that uroselectan is remarkably well tolerated in all surgical kidney diseases.

After intravenous administration, performance of which is very simple, films are taken at intervals, depending upon the rapidity of excretion. Fluoroscopy was also employed.

Reproductions of eight typical urograms are included.

EDWARD SCHONS, M.D.

Clinical Trial of Uroselectan. A. von Lichtenberg and M. Swick. Klin. Wchnschr., Nov. 5, 1929, VIII, 2089.

This new substance promises extensive clinical applicability of intravenous urography. The method offers satisfactory urography in cases of sufficient kidney function, and in all cases a roentgenologic function test, as well as a new chemical function test.

All cases examined with uroselectan were controlled by direct pyelography, and the results compared. Of 84 cases examined, the results were checked operatively in 35 cases, and by autopsy in one case. The results with uroselectan were technically successful and the films serviceable for diagnosis. No shadow indicated always either absence of the kidney or marked impairment of kidney function. The shadow was thus absent in advanced kid-

ney tumor, pyonephrosis, severely infected obstructed kidney; also in marked cardiac insufficiency. In all cases of marked or total obstruction, if accompanied by infection, the shadow was absent. In cases of hydronephrosis, ureteral stone, and high grade renal disease due to stone, excellent pyelograms were obtained. A very interesting case of closed tuberculous pyonephrosis showed cavities in the upper half of the kidney.

The method was used in nearly all forms of primary and secondary surgical kidney pathology. In prostatic hypertrophy the dilatation of the pelves and ureters was well shown.

Professor von Lichtenberg is very enthusiastic about the possibility of studying the function of the ureters.

In 61 out of 84 cases examined, fully sufficient information for the preliminary handling of the case was obtained, cystoscopy, ureteral catheterization, and pyelography being necessary in the remainder. In 75 cases information as to function was sufficient to determine the operative indications. In all cases the examination of the patient was expedited and simplified, and in 70 per cent more radical examination could be avoided.

Indications for intravenous pyelography are given as follows: (1) cases where direct cystoscopy, ureteral catheterization, and pyelography cannot be done because of anatomical, pathologic, or technical reasons; (2) cases of obstruction where direct injection can be done only to the point of obstruction; (3) where the ordinary method is risky.

No contra-indications are at present mentioned, but it is stated that so far the ureters are often better shown by the old method.

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